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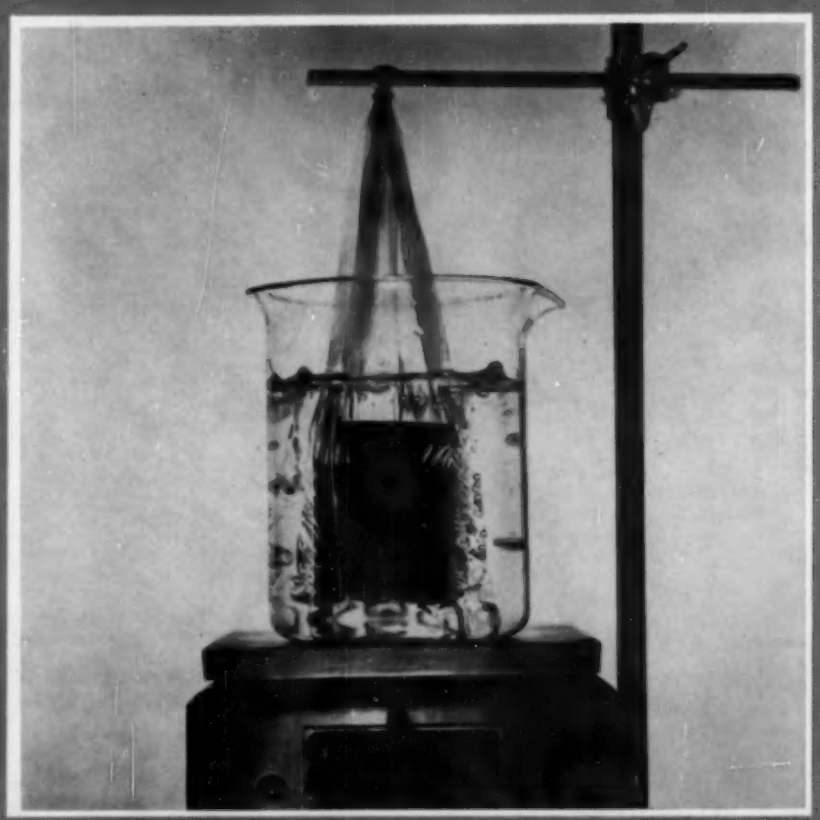

MEDIUM DENSITY RESINS ADD A NEW RANGE OF PROPERTIES TO ETHYLENES

page 29)

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AUGUST, 1958 • VOLUME 14, NUMBER 8

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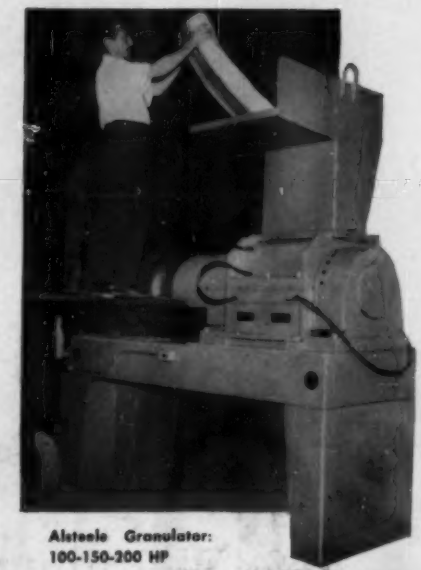

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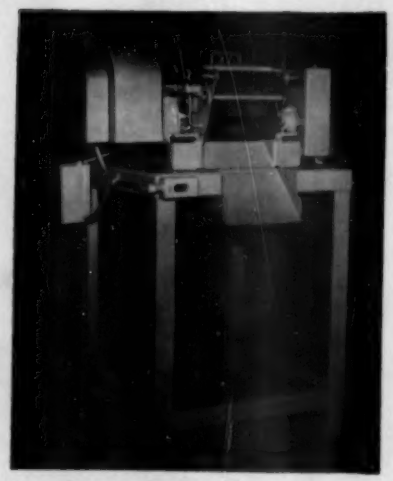
Additional features are excellent uniformity of pellets, and clean cutting action—even on elastomerics. A greatly lowered noise level is still another benefit.



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Here's a marine hawser that a man can throw with ease... wet or dry! Does not absorb water or freeze stiff in cold weather. Available in high visibility colors.

The best plastic cordage is made of MARLEX*

inexpensive... amazingly tough and durable!

Filaments made of MARLEX high-density polyethylene have a superior tensile strength of 50,000 to 130,000 pounds per square inch, depending on diameter and drawdown. This excellent strength is coupled with light weight. This means that you actually get about 50% more feet of rope when you buy MARLEX rope instead of an equal weight of manila. Furthermore, MARLEX rope averages one and a half times the strength of manila rope of equal size.

MARLEX rope has extremely good resistance to moisture and chemicals. It won't rot. You can put it away wet. No need to dry before storage.

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Investigate MARLEX—no other type of material can serve you so well—in so many ways—at such low cost.

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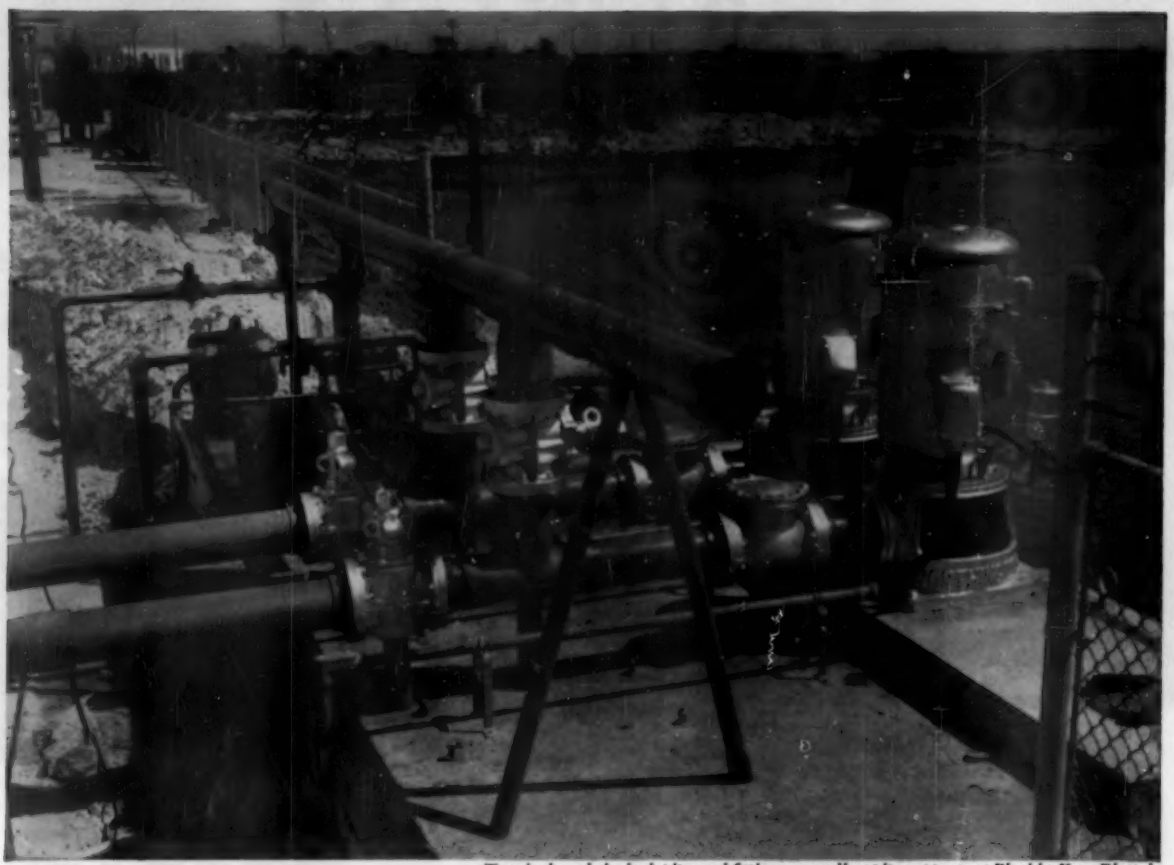

Two-inch and six-inch pipe and fittings, as well as pipe supports at Florida Keys Electric Cooperative, Marathon, Florida, are made from Geon rigid vinyl. B.F.Goodrich Chemical Company supplies the rigid vinyl material only.

Pipe of Geon cures corrosion caused by ground currents

SEA water is used in the raw water system of this diesel generating plant, and electrolytic corrosion of the metal piping in the raw water system created quite a problem. Then pipe made from Geon rigid vinyl was installed and, after two years of operation, there is no corrosion problem in the piping handling the sea water.

The addition of a larger diesel unit to the plant now calls for six-inch pipe made from Geon rigid vinyl to handle the salt water used in cooling the diesels and lubricating oils, and for piping Bunker C fuel oil from the oil storage tanks to the plant. Even the pipe supports are made from Geon rigid vinyl.

Pipe of Geon is the logical choice wherever corrosion causes problems. And there are installation savings, too. Pipe of Geon is lightweight and easy to handle. Contractors like it. Can be readily joined by solvent welding or standard threaded fittings.

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VOL. 14 AUGUST 1958 NO. 8

SPE JOURNAL

Published Monthly by
Society of Plastics Engineers, Inc.,
65 Prospect Street,
Stamford, Connecticut

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Non-Member Subscription Rates

DOMESTIC		FOREIGN	
1 Year	$ 6.00	1 Year	$10.00
2 Years	11.00	2 Years	16.00
3 Years	15.00	3 Years	20.00
*Single Issue	.65	*Single Issue	1.50

*Single issues older than 6 months are charged at $1.00, and single copies of the Roster Issue at $2.00.

● All copy intended for publication in the SPE Journal should be received at Stamford, Connecticut, by the first day of the month preceding publication.

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● Entered as second-class matter at the Post Office at Orange, Connecticut. Accepted at special postal rate provided in paragraph (d-2), Sec. 34.40, P.L. and R., of 1918.

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Photo courtesy of Spencer Chemical Co.

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Automatic, multi-zone temperature control insures high-quality nylon extrusions

This induction-heated Aetna-Standard extruder with a Kullgren Temperature Control System always provides exactly the right temperature for extruding nylon tubing, shapes, etc. Three zones of automatic heating, plus provisions for cooling in the alloy steel barrel of the cylinder extension and a separate heat zone in the high-pressure head, insure precision control. Warmup from room temperature to 400° F takes less than 30 minutes, to 600° F takes less than an hour.

Wheelco Model 403 multi-position type controllers are ideal for this application because they were specifically designed for processes where one instrument is required to control both heating and cooling cycles.

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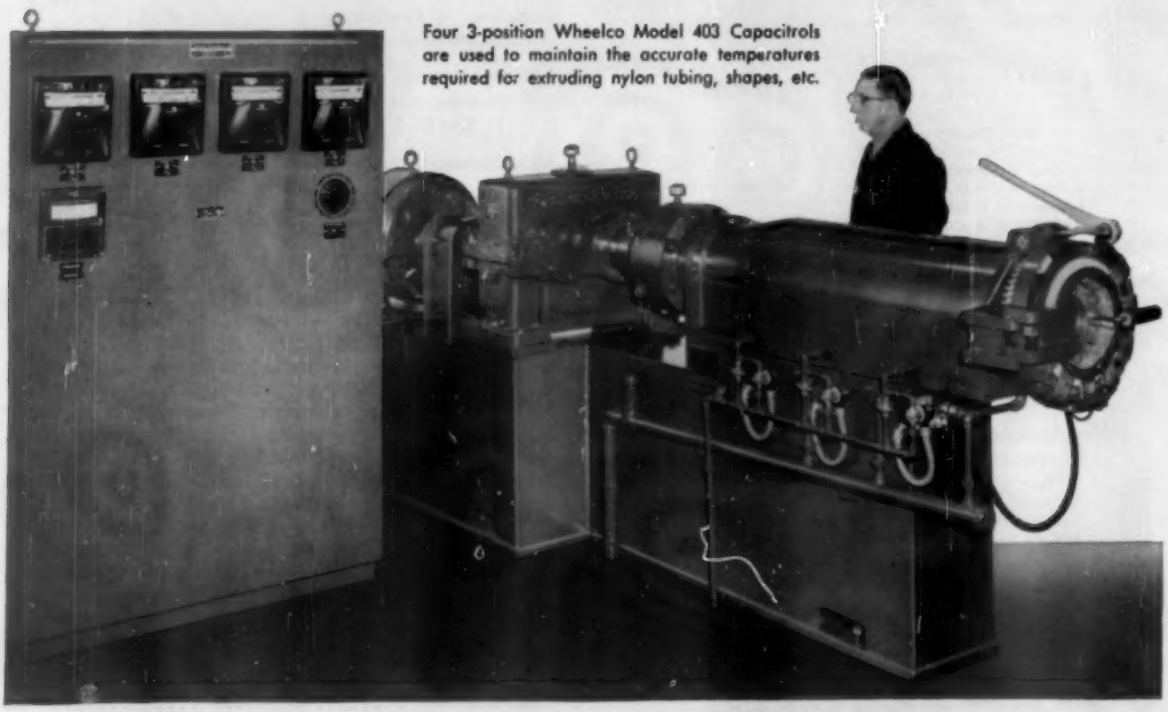

Four 3-position Wheelco Model 403 Capacitrols are used to maintain the accurate temperatures required for extruding nylon tubing, shapes, etc.

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From the Editor's Notebook

Charles E. Rhine

There's Value in Your Notes

I am sure that many of our readers have bits of interesting and informative technical data tucked away in their notebooks. I urge you to send them to me so their usefulness may be extended to all readers of the *SPE Journal*.

One of the foremost goals of the Publications Committee is to broaden readership and increase technical content of the *Journal* by working technical messages down into a brief, clear and precise presentation. The extent to which this condensing and revising technique can be applied varies with the nature of the subject and the scope of the investigation. Oftentimes it is found that the data can best be communicated in the form of notes.

In various publications these technical notes range from simple "How-to" items and shop problems to announcements of original scientific discoveries. Some magazines present these as letters from readers, and others as editorial fillers. Many society publications have found these notes to be a valuable adjunct to their regular technical papers section.

The *SPE Journal* has from time to time given its readers the benefit of such of these technical notes as came its way. Typical examples are "Service Report on Glass-Reinforced Plastics Tanks" by W. B. Sanford, page 52, April 1958 issue, and "Calculating PHR for Epoxies" by George Epstein, page 31, July 1958 issue.

However, in this issue we have recognized these contributions as a separate category in our index on page 7, and are herewith giving announcement that we shall actively pursue material with which to expand this phase of *Journal* services.

The style and presentation that these items will assume are exemplified by the technical notes mentioned previously and the one in this issue on page 23 entitled "Viscosity Conversion Nomograph" by Jerome Seiner. The length of these items may be as much as one page, but the prime consideration is the usefulness of the information to *Journal* readers.

In these technical notes, readers will gain capsules of information that can be quickly "taken" or filed for reference purposes.

Authors will find that these notes provide a convenient manner in which to establish prior claim and recognition for their discoveries where lack of time and additional information makes it impossible to prepare an immediate presentation in the form of a technical paper. It also provides an outlet for information that does not require the length and formal outline demanded of a technical report.

So won't you contribute your notes to this valuable extension of the *Journal's* technical service? We will be happy to receive them in whatever rough or extensive form they may be in. If suitable, we will edit them for publication under your by-line.

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Trans-Flo hose nozzle molded of Tenite Butyrate by The Vichek Tool Company, Cleveland 4, Ohio.

Four parts of **TENITE BUTYRATE** form this tough, lightweight nozzle

Here's a good example of how a switch to Butyrate plastic can mean an improved product, with savings in both material and manufacturing costs.

Four parts of transparent green Tenite Butyrate make up this product. Assembled in an adjustable, leakproof fit, they form an attractive and durable hose nozzle which sells at a popular price.

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And look how well Tenite Butyrate meets the performance needs: It is a tough plastic, virtually shatterproof and ready to take a good measure of abuse; yet, it's light in weight. It resists corrosion and endures outdoor exposure over broad variations in temperature and humidity. Color is an integral part of the product and will not chip off or wear away. Tests show the assembled nozzle has withstood water pressures up to 500 psi.

Remember this use of Butyrate whenever you need a tough, outdoor plastic, readily adaptable to design. Tenite Butyrate is available in a wide range of flows and colors for injection molding or continuous extrusion. Look into the design and economy possibilities offered by this versatile plastic. For more information on Tenite Butyrate or any other Eastman plastic, write EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE.

TENITE

BUTYRATE · ACETATE · POLYETHYLENE

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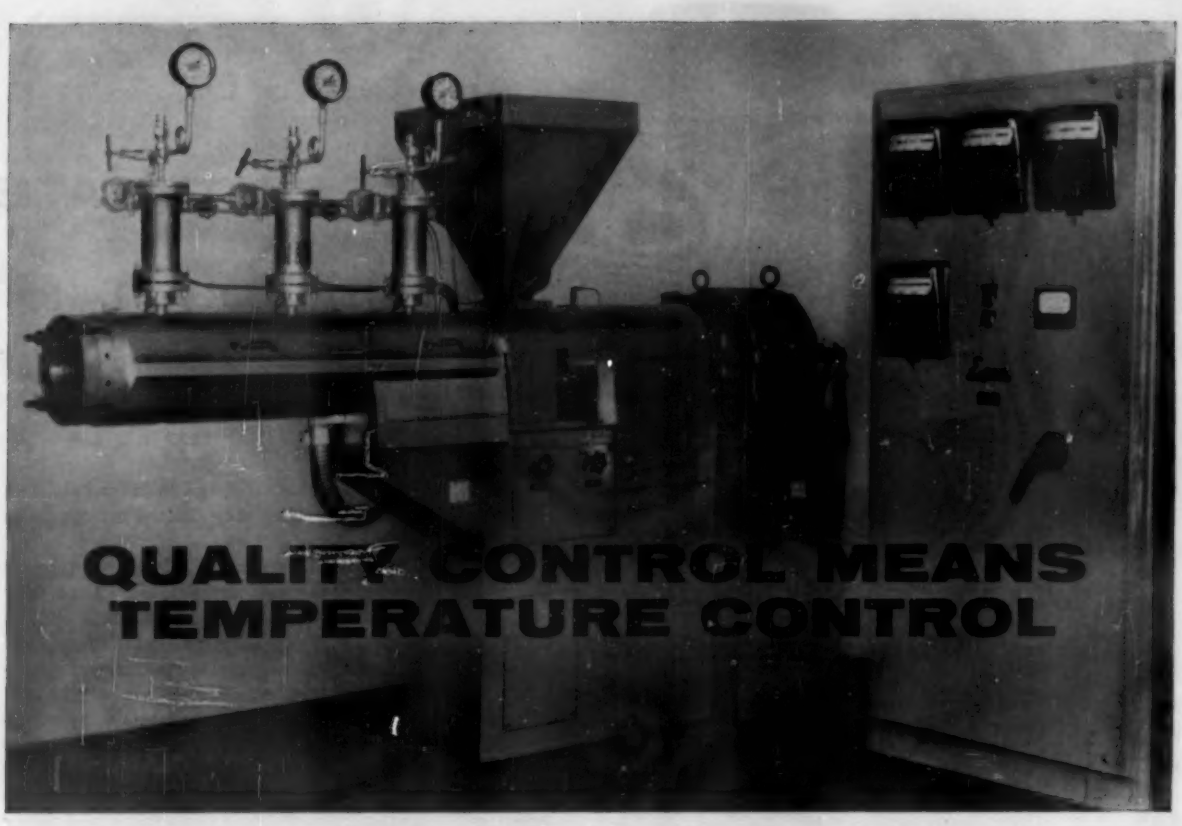

Egan Extruder With "Willert Temperature Control System" Automatically Eliminates Temperature Variations

Heating the plastic material in the extruder cylinder, whether by conduction, induction, or friction, is no problem — assuming the designer has provided sufficient heating capacity and a properly designed screw.

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LAMINAC *resin 4105*—a rigid, fast-curing resin of medium reactivity and low, slightly thixotropic viscosity formulated for boat builders and other fabricators using hand lay-up techniques. LAMINAC 4105 has good wetting properties, does not sag in vertical lay-up with glass mat or woven roving, offers fast gel controllable by amount of catalyst used, and requires short time between gel and cure to sufficient rigidity for removal from mold. These features enable fabricators to lay-up two or three parts per shift in each mold.

LAMINAC *resin 4103*—tough, resilient, new resin formulated for hot-press molding of products required to withstand heavy mechanical abuse, such as boats, auto bodies and truck cabs. Its resilience permits unusually fast cure without crazing and production of strain-free molded parts. Absorbing stresses, it maintains good glass-to-resin bond, giving permanent high mechanical strength. Favorable cure characteristics at room temperature with addition of recommended promoter-catalysts.

LAMINAC *resin 4107*—this new resin is intended primarily for tanks, tank linings, ducts and other applications requiring high degree of chemical resistance. Laminates show excellent resistance to boiling water, acids and mild alkalis. The resin has excellent curing characteristics, permitting curing of thick sections with minimum crazing. It is suitable for fast high-temperature molding as well as all other fabricating methods.

Technical data sheets on the new LAMINAC *polyester resins are available on your request.*

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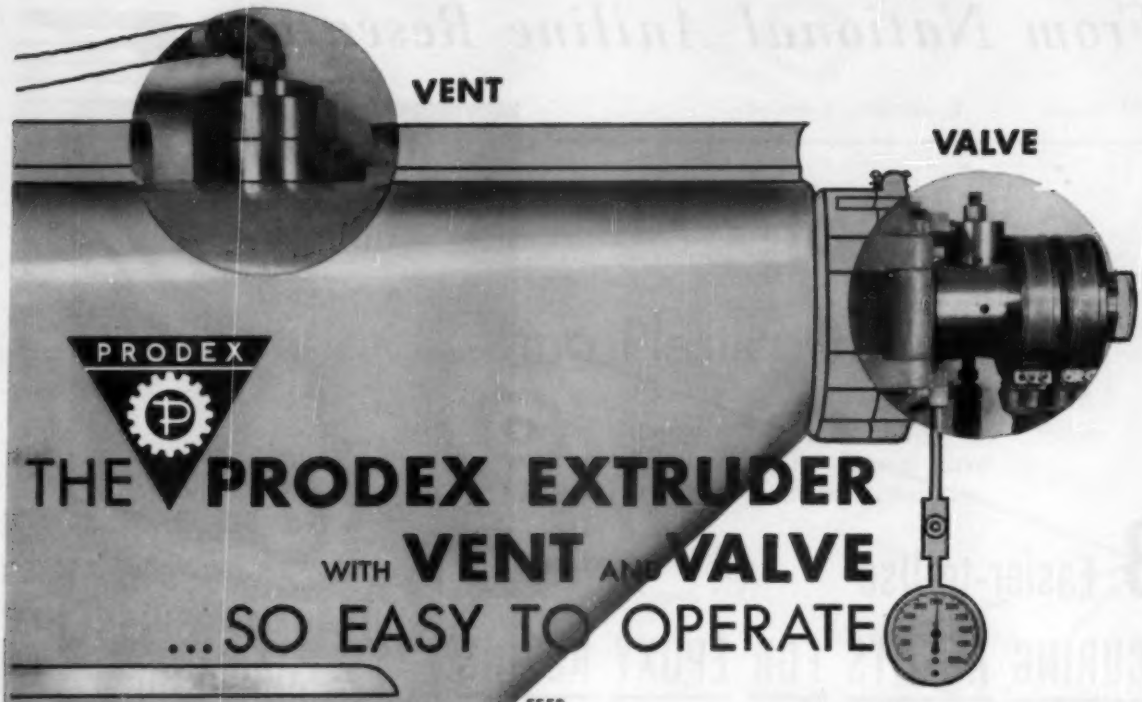
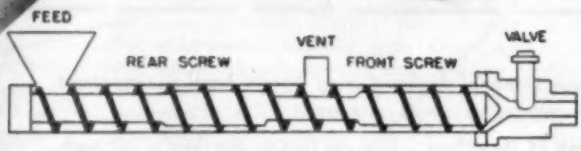


PRODEX

THE PRODEX EXTRUDER WITH VENT AND VALVE ...SO EASY TO OPERATE



The combination of a TWO-STAGE extrusion screw with VENT and VALVE gives these advantages:

* **HIGH OUTPUT.** The rear screw determines the high output rate of this machine because it is not subjected to die back pressure. Easy valve adjustment permits the same output rate (lbs./hour) for a wide range of die openings.
* **CLOSE TOLERANCES.** Since the front screw is fed a hot melt of uniform viscosity, a constant pumping pressure is easily maintained by valving, resulting in close tolerances.
* **NO POROSITY.** Venting with or without vacuum continuously extracts air, moisture, monomer and other volatiles. High volatile content can be readily removed.
* **BETTER DISPERSION.** Two stage extrusion with intermediate relaxation and reorientation provides high intensity mixing. Valving permits controlled mixing in front screw.
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PRODEX Vented Extruders are used successfully in sheet and shape extrusion of H.I. Styrene, ABS polymers and methyl-methacrylate without pre-drying; wire and cable coating and shape extrusion from vinyl dryblend as well as in a wide variety of process applications where monomer, solvents or moisture must be removed in large quantities.

No matter what thermoplastic material you now use, the PRODEX extruder will help you get better results. Arrange for a production-line demonstration today with your material.

50 PAGE ILLUSTRATED BULLETIN E-3 gives complete details about PRODEX EXTRUDERS.

Package installations for sheet, film, pipe, wire and cable, continuous compounding and laminating. PRODEX extruders are available in 1¾", 2½", 3½", 4½", 6" and 8" sizes.

PRODEX

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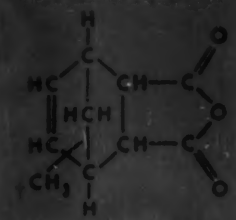
MALEIC ANHYDRIDE • PHTHALIC ANHYDRIDE

METHYL NADIC® ANHYDRIDE



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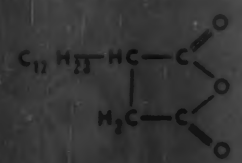

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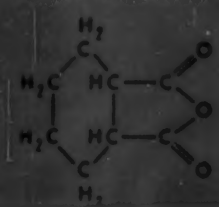

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PLASTICS ENGINEERS JOURNAL

Volume 14, Number 8 • August, 1958

Europe's Growing Plastics Industry

Plastics research, engineering and manufacturing developments have stimulated new ideas in materials and methods, and have led to rapid growth of the industry in many European countries.

Zoltan Merszei

Dow Chemical International, Ltd.

AFTER CENTURIES of wars, poverty and backwardness, a new Europe is being born. Many believe the birth will be successful, and within 15 to 20 years Free Europe will be a single mass market of about 370 million consumers. During the past 10 years, a deep-seated change has occurred in the economic life of Free Europe: in the new distribution of income, in the mushrooming self-service stores, in the traffic-jammed city streets, and in the expansion of most industries.

Since 1950, expansion in the chemical industry has been greater than in industry as a whole; one of its segments, the plastics industry, has reached the point where it approaches, both in size and in technical knowledge, that of the United States. This development is the result of a torrent of progress which began at the end of World War II when, for the first time in history, a free flow of people and ideas started to cross the Atlantic. From the new world came ideas on the efficient and profitable use of new materials originated in European laboratories.

Europe is in an economic ferment; an industrial renaissance is occurring inside its frontiers. During the past decade the plastics industry has registered significant developments embracing numerous materials and products. Many production and marketing methods have been Americanized.

Progress in Materials

In the acrylics field, a German firm introduced a high molecular weight material with improved chemical properties and also presented acrylic copolymers with lower softening points. All these materials can be either molded or extruded. Among products recently placed on the market are a bathtub fabricated from acrylic material and centrifugally cast acrylic tubes in diameters up to 18".

Nylon-type materials are now being produced in seven countries; a number of fabricators who specialize in nylon processing have built a world-wide reputation for their products. Much of the nylon production is of the caprolactam-nylon-6 type. Other nylons produced are based on adipic acid and diamine (nylon-66 and -610) and nylon-11, which is derived from 11-amino undecanoic acid. Notable among new nylon products are centrifugal castings and extrusion moldings made by relatively new techniques; nylon packaging film which can be boiled, heat-sealed and printed; car dashboards and bicycle saddles.

Polystyrene, until recently the work horse of the molding industry and one of the oldest European-discovered thermoplastics, provided much of the stimulus which started the present growth. About 18 producers manufacture most of the types which are known today in the United States. French, German, and Italian fabricators who specialize in vacuum forming of high impact sheet are producing some articles of exceptionally high standard; for example, the complete refrigerator inner box with up to 11-cubic-foot capacity at present being fabricated in France and Germany.

The Polyethylenes

Low-density polyethylene continues to be in short supply, although it is estimated that within two years Europe will have more than sufficient production to cover its requirements. In addition to its success in the general molding, squeeze bottle and pipe extrusion fields, this British-developed material is feverishly conquering ground in the packaging industry, both as film and as a coating material for paper. Great interest is attached to polyethylene film laminated with materials such as cellulosics and aluminum foil. Consumption is also increasing in polyethylene reinforced with an open mesh woven textile like glass-fiber or Terylene (British polyester fiber.) Extensive research is being undertaken in the irradiation of polyethylene; one British firm has introduced commercially an irradiated polyethylene for wire insulation.

Because of a growing interest in the higher-density polyethylenes, several companies, using most of the known processes, are building units for the production

This paper was presented at the Fourteenth Annual Technical Conference of SPE.

of linear low-pressure polyethylene. Apparently European producers, in contrast with the Americans, were not frenzied into acquiring the Ziegler process; the quantities of the material which so far have been used commercially are small when measured by American standards.

However, there is no question in the European fabricator's mind that the low-pressure polyethylenes, with their great processing and application possibilities, will have a tremendous impact on the plastics market.

Several companies are working to establish the long-term strength properties of low-pressure polyethylene pipe as compared with unplasticized PVC pipe. Regarding the manufacture of pipe, one company suggests that induction heating of the mold results in a more uniform tube wall. It is claimed that pressure calibration gives a better surface than vacuum calibration; annealing the pipe with water at 100°C is also advocated to give a better stress corrosion resistance. Combining lower-molecular-weight material with a smaller amount of higher-molecular-weight material is believed to result in a better compromise between processability and long-term strength properties. Fittings of polyester-glass fiber are recommended; assembly is effected with a polyester glue.

Propylene, Vinyl and Amino Plastics

Alongside low-pressure polyethylene it is necessary to mention polypropylene. Developed in Italy by Giulio Natta, who claims it may become one of the cheapest thermoplastics, this material is produced commercially on a somewhat limited scale by Montecatini. It is available in a low-molecular-weight material suitable for film and blown containers, and in a high-molecular-weight material suitable for injection molding and extrusion. The most interesting feature of the material is its thermal resistance above 100°C.

With the exception of a high-impact unplasticized PVC marketed by a British firm, no other new vinyl materials have appeared recently. PVC and some other vinyls are produced in nearly every European country; a few of these nations have surpluses in production capacity and available material. Considerable progress has been made in new applications such as self-adhesive vinyl sheet for wall covering, corrugated PVC sheet for illuminated ceilings, and nonflammable corrugated PVC sheet for transparent roofing.

A British firm is marketing two grades of melamine formaldehyde molding powder, one asbestos, the other nylon-filled. Increased interest is shown in the melamine laminates particularly in the development of post-formed materials. The drive to sell melamine laminates for other than kitchen usage encouraged striking patterns.

Reinforced Plastics

Comparatively low labor costs, plus the availability of numerous artisan-type workshops, explains the progress achieved in the fabrication of reinforced plastics. Dinghies, canoes, trailers, radar scanners, radomes, structural aircraft components, translucent corrugated panels, wheelbarrows and washing machine tubs represent only a few of the larger items which are regularly manufactured in nearly all European countries. Among recent developments is a glass-fiber reinforced epoxy molding powder introduced in Switzerland by Ciba. The optimum length of the glass fibers is 6 mm. The molding temperature is 160°C; molding time is 10 to 15 minutes. The after-treatment recommended for the molded material is 1 to 2 hours at 100 to 120°C.

Plastics Foams

The use of plastics foams has increased considerably within recent years. In addition to the well-established flexible polyurethane foam produced in blocks by a German process, a British firm is marketing a rigid polyurethane foam manufactured from an alkyd/isocyanate combination. Foamed-in-place polystyrene based on German knowledge is now fabricated with increasing success in several countries. Perhaps the most important future can be predicted for flexible and rigid PVC foams fabricated from the lowest-cost thermoplastic material in Europe. Several companies are searching for the ideal way to manufacture foamed plastics. At present three major methods are employed: One requires the mixing of the plastics with gases, producing foam at room temperature; another requires the mixing of the plastics with soluble gases or liquids at room temperature, creating foam through heating; the third involves the mixing of plastics with chemicals which decompose. PVC, plastisol and polyurethane foams are manufactured basically by the first two methods (CO_2.) The foam obtained in this way has an open structure. One German firm, Bayer, advocates the third mode. The chemical method is claimed to have an advantage over the physical methods because the reactive agents can be handled more easily and capital investment is lower.

Plastics Equipment

Plastics processing and fabricating machinery covering nearly every facet of the industry is manufactured on a rather large scale in Germany, Great Britain, Italy and Switzerland. A wide range of plastics-processing equipment is also manufactured in the remaining countries. The four nations mentioned produce extensively for export; many of the machines have achieved world-wide reputation for quality and mechanical competence. The development is particularly remarkable in the injection molding and extrusion machinery field since, until the Korean crisis, the plastics industry of every European country was dependent mainly on imported equipment.

Injection Molding Presses

In the injection molding field the emphasis is on machines up to 12-ounce plasticizing capacity, although there is a variety of machines manufactured up to 350-ounce capacity (Truzzi.) Of special interest is the Ankerwerk single-screw preplasticizing and injection machine, claimed to double its maximum shot in plasticizing capacity and inject improved thin-walled components with better homogeniety. Windsor, one of the larger machines which molds up to 72 ounces of polystyrene, incorporates a twin-screw single-stage preplasticizing unit which is slide-mounted and retractable. One of several fast-cycling machines which have been developed, Windsor 20, has a capacity of 5 ounces in polystyrene with a cycling time of 400 shots per hour. A recently-introduced low-pressure injection machine, Foster-Wucher, is used in the production of vinyl footwear. Also, a number of American machines are manufactured under license.

Extrusion Machinery

In extrusion equipment, one British manufacturer of double-screw extruders has introduced a single-screw machine in conjunction with a complete polystyrene sheeting plant. The machine has a 20:1 length-diameter ratio; it embodies hydraulic variable drive with controlled torque, barrel heating by induction and inde-

pendent zone-controlled cooling, a one-piece barrel, and an easily detachable die adapter.

Kraus-Maffei, a German manufacturer, has made its debut into the plastics field with a single-screw extruder of novel construction. The machine employs a verticle screw 16 mm in diameter, the end of which is formed as a conical "ridged head" where heat is generated by friction in the material. The trend is toward adiabatic extrusion, but not to such an extent that all additional heating is omitted. The screw turns slightly faster than normal (maximum speed is 120 rpm) and it is hollow for cooling purposes. The core of the screw is progressive 1:1½. It is claimed that the vertical screw results in better feeding because of improved granule flow.

Another German manufacturer, Reifenhäuser, has built an extruder for high-impact polystyrene sheet production with a 150-mm diameter screw 3 m long and a die of 1,100 mm length. Where previously only American-made extruders were used, extruders manufactured by German and Italian companies are now employed for a wide range of fabricating.

Compression Molding

Equipment manufacturers of Europe have long been proficient in the manufacture of compression molding presses. Lately, tremendous strides have been made toward improving the working efficiency of present presses, and some notable results have been achieved, especially by the Germans and the Italians. One German company is offering a 4/2 automatic quadruple molding machine for phenolic and amino plastics. The machine operates on a fixed cycle: adjustment for different components is obtained by varying the cure time and temperature.

European fabricators were experienced in vacuum forming plastics sheets long before the last war; therefore, when heat-formed polystyrene sheets appeared on the market, about 12 companies immediately started to manufacture and sell vacuum forming equipment. As the interest in thermal forming technique continues to spread, equipment manufacturers remain in a good position to develop machines providing intricate fabricating possibilities. A number of these machines are suitable for producing large as well as small moldings. Small moldings with walls as thin as 0.004" are manufactured at high speed.

Other European processing machines posseas novel features. A British company has introduced continuous metalizing equipment for aluminizing plastics sheet at speeds up to 600 fpm. A German firm has developed a blow-molding unit permitting the manufacture of articles such as plastics bottles on standard injection machines. Another machine developed in Germany embodies the melt-coat principle: papers, textiles and other webs can be coated automatically. The finishes obtained can be satin, high-gloss, embossed, clear, translucent, opaque or colored.

European Research in Materials

From the foregoing information it can be surmised that, as a whole, the European plastics industry has progressed to the point where it could soon reach the high technical levels prevalent in the United States. Extensive basic research in Europe has contributed generously to those technical standards which have enabled industry there to be first with many plastics. Acrylonitrile was invented in Germany, as was nylon-6 from caprolactam and polycarbonates. Rilsan fiber, a polyamide similar to nylon, was developed in France. High-pressure polyethylene and polyester fiber and film were introduced in England. Polyethylene by the Ziegler low-pressure process was first produced in Germany. The process for producing isotactic forms of polyolefins, such as polypropylene, was developed in Italy.

Europe, unlike the United States, still does not represent a single economic unit; its plastics progress is influenced and affected by numerous local factors. In order to understand this situation, it is necessary to review the growth of plastics in some of the individual countries which will eventually become part of the single mass market mentioned earlier.

GERMANY

Until the end of World War II, Germany and the United States were the leading plastics producing countries. As a result of the war, however, Germany temporarily lost its position as a large producer of plastics.

Germany's peak year in the plastics field was 1944, when 550 million pounds were produced. In 1947, however, production was down to 51 million pounds. Formerly a plastics export country, Germany was forced to import considerable quantities of materials during the first few years after the war. Within the five years following 1947, Germany was able to increase plastics output to 400 million pounds, and by 1957 it exceeded one billion pounds. Thus, Germany once again gained second place.

About sixty companies of various sizes shared in Germany's 1957 plastics production. Five of these firms accounted for approximately 75% of the total.

Materials

The largest production is enjoyed by the polymerization resins, followed closely by condensation products, and at a great distance by cellulose derivatives. Within the polymerization resins field, a significant increase in production was registered, particularly in polyvinyl chlorides, polyvinyl acetates and polymethyl methacrylates. Production in the condensation products kept pace with the general development, but during the past years, cellulose derivatives have remained static in spite of a sharp increase in the production of transparent cellulose film.

Vinyls stand at the peak of plastics production; six companies are producing a total of 330 million pounds. In addition to emulsion polymers, suspension polymers are also being produced to an increasing extent. Approximately 150 million pounds of PVC were consumed domestically in 1957; slightly less than half was used for film, artificial leather and floor coverings; 35% for cable insulation; 15% for tubes, profiles and extrusions; and another 10% as hard PVC employed mainly for the manufacture of pipes.

Another important group consists of polyvinyl acetate and its products. Polyvinyl alcohol recently came into use as film for packaging pest-control agents and as a covering for molds in processing reinforced polyesters.

Polystyrene, the second most important thermoplastic in Germany, still constitutes the major portion of materials used in injection molding household articles and industrial parts. Total production is in excess of 55 million pounds per year. Polystyrene foams are attracting attention both for acoustical and thermal insulation.

Low-density, high-pressure polyethylene is produced by two companies. Last year production was estimated to be in the range of 16 to 20 million pounds. Current facilities are being expanded, and total production is expected to reach 70 million pounds within 18 months, thus making Germany self-sufficient re-

garding this product. In addition to the locally produced material, approximately 16 million pounds of polyethylene were imported last year, primarily from the United States and Great Britain. Thus, the total amount of 36 to 40 million pounds of low-density polyethylene processed in Germany has been employed to the extent of 33% each for films and injection molding, 15% for pipe, 12% for bottles, and 3 to 4% each for cables and various other uses.

The most important recent development has been the Ziegler low-pressure process for producing high-density polyethylene. It is expected that within two years Germany should be producing enough of this material to take care of its own requirements and also have a surplus for export.

About 25 million pounds of polyacrylates and methacrylates were produced in 1957. Developmental work has resulted in an improved adaptability to the needs of end users, particularly for window glazing, signs and lighting fixtures.

The most important group of condensation products is still phenolics; total production in 1957 reached about 170 million pounds. In the amino field, melamine resins are meeting with favor, especially for molding. Various types of amino resins enjoy wide use in laminates for the furniture industry.

Polyesters have been produced in Germany for several years. In unsaturated polyester resins, emphasis is placed on large objects in the building field. Polyesters are also used in all types of containers and in boat construction. About 8 million pounds of unsaturated polyester resins were produced in 1957. In addition to polyesters, reference should be made to the polyterephthalic acid esters being employed in Germany, not only for synthetic fibers, but also for the production of sheets with exceptionally high mechanical strength.

Polyamides are produced both from caprolactam and from adipic acid-hexamethylene diamine. Of the material sold in the form of compounds, about 4 million pounds were used in injection molding and the remaining amount for sheets, belts, filaments and tapes. Important to the development of the polyamides was the increased use of injection molding compounds. New high melt viscosity compounds which open up possibilities for the production of articles by extrusion and blowing processes were developed recently.

In the form of foams, the polyurethanes represent one of the most interesting of all German plastics developments of current times. These foams are now produced in both rigid and elastic states.

Equipment

Germany has a highly developed plastics processing industry. About 600 of the 1500 companies which process and fabricate plastics operate injection molding machines. Unfortunately, there are no statistics available on equipment installed before and during World War II. However, it is known that since 1946, about 3,500 injection molding machines and approximately 1,300 extruders have been put into operation. About 10,000 compression presses take care of the processing of thermosetting materials.

The plastics processing industry, like materials production, has experienced growth of approximately 30% per year during the past eight years.

GREAT BRITAIN

While American manufacturers were eager to try out plastics, the conservative British manufacturers were, generally speaking, slow in accepting these new raw materials in their processing operations. However, war-time applications helped to break down the traditional British approach to anything new. Although right after the war progress received a setback due to failure of products and misapplications, the development of plastics continued to gain ground until it eventually became one of the most rapidly expanding segment of the British industry.

Materials

1955 was a record year for British plastics. At 640 million pounds there was an increase of 17% over 1954 and more than 100% over 1950. It is estimated that 1957 production of materials will reach 750 million pounds. Most of the increase during the past two years can be accounted for by gains in production of PVC and high-pressure polyethylene. In addition, expansion took place in the production of polymethyl methacrylate sheet and polytetrafluoroethylene. A noteworthy feature of the British plastics industry is that thermoplastics represent over half the total production of plastics—a sharp contrast to 1950 when the ratio was 2:1 in favor of thermosets. In the thermoplastics family, emphasis remains on the big three: polyvinyl chloride, polyethylene and polystyrene.

PVC production, which is in the hands of three producers, has increased over the past four years at the rate of 20 million pounds per annum. Until recently, the present 120 million pounds constituted the largest single plastics group.

The closest rival to PVC is high-pressure polyethylene which by the end of 1958 may reach a production rate of about 180 million pounds per year. In addition to ICI—discoverer of this material—two other firms will be producing high-pressure polyethylene during 1958; at least two additional companies have well-advanced plans for producing low-pressure polyethylene. With so much accent on polyethylene of both the low- and high-pressure varieties, it is not surprising that during the past year ICI was able to announce the development of a non-catalytic material. This material has increased density, and is claimed to withstand sterilization at 100° C.

Generally speaking, polystyrene production growth has not lived up to the expectations of a few years ago. Some markets, previously conceded to polystyrene because of price and ready availability, have been recaptured in part by the tougher cellulosics.

Though not spectacular, the increase in phenolics has been steady and production is now approximately 70 million pounds. On the amino plastics side, production has reached 55 million pounds per year.

Polyester resins, which have tended to lag for some time in Britain, attracted renewed interest during the past year; today production is estimated at about 3 million pounds annually.

Equipment

An estimated 950 injection molding machines, with plasticizing capacity of about 5,500 ounces, are presently operating in Britain. There are also nearly 3,300 compression presses in operation, aggregating 280,000 tons. In addition, 65 companies operate extruders and other advanced plastics processing equipment.

For a number of years the chemical engineering of Britain's plastics industry, particularly in the injection molding and extrusion fields, was far ahead of mechanical engineering. British engineers are rapidly gaining lost ground, however, and world-wide interest is focused on the many new British-made machines which have been introduced recently.

In general, the structural use of plastics in Britain has lagged behind that in the United States, Germany, France and Italy. Plastics have been used primarily

for cladding other materials. But now there is an increasing number of companies prepared to utilize plastics on an ever-widening scale.

FRANCE

Plastics output in France rose from 210 million pounds in 1955 to 285 million pounds in 1956, and it was expected to reach the 330-million mark during 1957. These figures, if expressed percentage-wise, represent an increase in output unparalleled in any other major producing country. (1955 to 1956 increase in France 34%, United States 30%, Germany 20%, Britain 4%.) The French plastics industry, which was somewhat static during and immediately following World War II, has developed rapidly and continues to expand. Today France still rates fifth as a plastics producer, preceded by the United States, Germany, Britain and Japan; however, it is believed that this position could easily improve during the next two years.

Materials

While French plastics materials are produced primarily by the larger chemical companies, there are about 2,500 enterprises, mostly small, which fabricate plastics articles.

PVC, with a total of approximately 90 million pounds, is the number one plastics produced in France, followed by polystyrene, which during 1957 reached an output of nearly 50 million pounds. Of the other major plastics materials produced in France, phenolics have surpassed the annual output rate of 35 million pounds; amino resins are produced at the rate of 20 million pounds; cellulosics and polyethylene each reached 12 million pounds during the last year. Polystyrene, polyethylene and silicones are produced under foreign patents; polyvinyl chlorides, phenolics, polyesters and cellulosics are produced mostly under French patents.

Research is well developed among the larger producers of materials. Standards of quality are slowly being developed and established through industry-government collaboration. In addition to individual company research, a center for plastics materials confines its work to technical problems in the utilization and adaptation of plastics. Its studies are in the fields of molecular mass and structure; electrical properties; thermal, mechanical and physical chemical properties; and processes and equipment employed in the manufacture of plastics articles.

Equipment

The plastics industry is centered mainly in Paris, Lyon, Oyonnax and Miru. In each of these areas the fabricators tend to concentrate on production of certain articles. Among the fabricators, 820 operate injection molding machines; 500, compression presses; 230, vacuum forming and sheet working equipment; and 135, extruders. Furthermore, there are 67 companies calendering, and a score of other fabricating and processing plastics by every known method and with every type of equipment.

In the injection molding field, it is estimated that there are in France, some 3,500 machines representing a total capacity of 8,500 ounces. The capacity of these machines ranges from ½-ounce hand-operated presses to at least 200-ounce automatic machines. Many of the injection molding machines are now manufactured locally; several are under license from American and Italian manufacturers. However, about 60% of the existing machines, particularly the larger ones, are still imported.

Currently there are also 3,700 compression molding presses in operation. This segment of the industry is more highly concentrated than is indicated. It is estimated that two molders account for 30% of total production; five companies probably account for 55% of the output in the field.

In contrast with Germany, the French plastics industry is burdened with high costs of raw materials and labor; consequently, prices average about 30% higher than those of the principal foreign competitors. This problem is related to the manner in which the industry was developed, coupled with high cost of electric power, higher wages paid to women, social security payments amounting to 40% of salary, and continued opposition to specialization, standardization and mass production methods.

In spite of these difficulties, future prospects are considered good for the French plastics industry, which since 1950 has had a five-fold increase in production output.

ITALY

For the past several years Italian consumption of plastics has increased by 25% per annum. With a constant improvement in living standards, and with increasing public confidence in plastics, the growth rate may be more pronounced in the years ahead. At present, Italy ranges fourth among plastics material producing countries in Europe, and accounts for about 5% of the world production of plastics.

Materials

There are today approximately 20 synthetic resin producers responsible for over 80% of the 220 million pounds of plastics material produced in Italy. This quantity is considerably greater than the needs of the present domestic market; therefore, there is an excess of exports over imports. As all types of plastics materials of importance are produced in Italy, the processors have an almost complete assortment of materials available for fabricating.

Among the materials produced in Italy, the aminos account for the major share of the plastics industry. There is a large consumption of urea molding powder since its adaptability to bright colors appeals to the public. Melamine molding powders are used principally for the manufacture of household items and for decorative laminates.

Second in importance among materials are the vinyls. PVC production is greater than consumption, and a fair amount is exported to various countries, including the United States. Italy, like Germany, has experimented extensively with rigid PVC. The extrusion of rigid vinyl in Italy is based on well-developed knowledge recognized throughout the world.

Phenolic molding powders are employed for all standard articles manufactured in most other countries.

Polystyrenes are now produced by three concerns. In addition to the usual methods of producing and finishing polystyrene articles, the technique of high vacuum metalizing is widely employed.

Italy was the first country in continental Europe to produce polyethylene by the high-pressure method. About half the output is used for the manufacture of blown films, but the production of extruded and blown bottles, containers and drums is increasing rapidly. Italian scientists were the first to apply the Ziegler principles to the polymerization of other gases such as propylene. Polypropylene is now available in increasing commercial quantities.

Reinforced corrugated roofings are the chief application of the polyesters, especially in Southern Italy. Generally speaking, most conventional low-pressure molding methods are employed.

Equipment

Injection molding machines up to 150 ounces are manufactured; some are suitable for molding all types of thermoplastic materials including rigid PVC. Among the extrusion machines there is a special patented model with which pipe and irregularly-surfaced items can be covered to a uniform thickness.

According to a 1956 census, there were 1,250 plastics processors in Italy utilizing 1,650 injection molding machines, 3,100 compression presses, 1,200 extruders and 24 calendering machines, plus a large assortment of additional equipment. Italians traditionally possess high technical and tooling skill; while some countries tend toward uniform production on restricted quality standards, production in Italy is characterized by a vast number of different patterns, types and qualities.

Italian plastics engineering embraces every technique known in other lands, and Italian ingenuity has refined and improved many of these methods. Good examples include vinyl coated fabrics with the quality of "breathing" and the production by continuous process of corrugated polyester laminates.

SWEDEN

The plastics industry is growing more rapidly than any other industry in Sweden. Production of plastics materials in 1954 was estimated at 61 million pounds —an increase of about 100% over 1950; for 1957 the figure is estimated at 80 million pounds, or more than twice the total production volume of plastics in the other three Scandinavian countries.

Materials

About 700 companies are directly or indirectly connected with the plastics industry in Sweden. Of these, approximately 30 account for 90% of all the plastics materials manufactured.

In addition to polystyrene, a good number of cellulosics are produced, including regenerated cellulose, nitrocellulose and carboxymethyl cellulose.

The vinyl industry is well-developed and allows for some export.

Phenolics have been produced in Sweden since 1919. Phenolic molding powders are manufactured by three firms which also produce fabric-based phenolic laminates. Decorative laminates are one of the greatest sales successes in the Swedish plastics industry. Total production of all phenolics for 1957 is believed to be about 8 million pounds.

Two companies are manufacturing unsaturated polyester resins for reinforced plastics. Current consumption of polyesters is about 1 million pounds per year; most of this amount is supplied by domestic producers.

Fillers such as wood flour and alpha-cellulose are produced in large quantities by several companies and are also being exported. One firm has started to manufacture fibrous glass, and one is manufacturing glass cloth.

Equipment

The number of injection molders in Sweden is about 230, and the total number of injection molding machines in all capacities is nearly 500. During the past few years the number of injection molding machines has increased by about 8% yearly, mainly in the category ranging from 3 to 8 ounces. Some companies have larger machines, and there are several 48- to 60-ounce machines in operation. The number of compression molders can be estimated at 150, ranging from very small firms to a few large companies possessing several hundred presses.

The vinyl processing industry is well developed and holds a reputation for high quality. Among 70 processors, several manufacture calendered film and sheeting; others are equipped for coating fabrics and paper with PVC; a number manufacture PVC flooring materials; and still others process plastisols by dip coating. There is one firm extruding rigid PVC; a few others are equipped for hot gas welding and fabricating of rigid PVC; and two companies manufacture PVC-based phonograph record compounds.

The interest in reinforced plastics is extensive; a dozen companies have entered commercial production. One firm is manufacturing various types of small boats; while another is producing tanks for transporting gasoline, oils and other fluids. Some companies manufacture parts for aircraft and other military equipment. There are also three firms making corrugated sheets of glass-fiber reinforced plastics.

Of the extruders, several are large-volume producers of polyethylene tubes and blown polyethylene film. One manufacturer of viscose film also makes cellulose acetate and polyethylene film.

Interest is growing in vacuum forming; at least a dozen companies are equipped with vacuum forming machines. One company in the extrusion field is already producing extruded polystyrene sheets.

The number of firms equipped for high-frequency welding of film and sheeting is steadily increasing. One firm has developed a special tetrahedron-shaped package for milk and cream. Made on special equipment from paper coated on the inside with polyethylene, the package is rapidly gaining world wide acceptance.

Much of the machinery and equipment for plastics processing has to be imported, although a few companies have standard lines of compression presses, injection molding machines, and high-frequency welding equipment.

Most of the larger companies equipped for compression and injection molding as well as vacuum forming usually manufacture their own molds; however, there are several firms which specialize in this field.

Plastics products, most of which reflect high quality workmanship and modern design, are enthusiastically accepted by the Swedish public. This sympathetic attitude assures the Swedish plastics industry of continued growth.

OTHER EUROPEAN COUNTRIES

About 90% of the total European plastics output of approximately 2.4 billion pounds is accounted for by Germany (40%,) Great Britain (30%,) France (12%,) and Italy (9%.) Of the remainder, Sweden claims 3%; the balance is shared principally by the remaining Free European countries.

THE BENELUX NATIONS

In the Benelux countries production and consumption of plastics rose by about 19% per annum during the last three years. The interest of these countries in plastics embraces most of the known materials and processes, although at present only some of the materials are produced locally. Caprolactam-type nylon made in the Netherlands deserves mention. Both Belgium and the Netherlands produce vinyls, various cel-

lulosics, acrylics and polyesters. Soon there will be units producing low-and high-pressure polyethylene. In the Netherlands, industry, with the collaboration of the Government and the universities, maintains a well-equipped plastics institute whose efforts are chiefly responsible for the high quality of the country's processing techniques.

SPAIN

In Spain, the processing portion of the plastics industry has grown much faster than the materials section. The processors, numbering about 1,000, must depend on imported materials, except for phenolics, certain aminos and some PVC and acrylic. For the past three years, the economy of Spain has been undergoing radical changes; there is hope that the plastics industry will be among those to benefit. Ambitious plans are in the making: production of both polyethylene and polystyrene is expected to begin in Spain during the next two years.

SWITZERLAND AND AUSTRIA

Twenty years ago there were only about a dozen plastics molding and fabricating plants in Switzerland and Austria. Today, in these two countries, there are over 300 fabricators processing approximately 60 million pounds of material annually. More than half of the total—including melamine, urea, phenolics, PVC and even nylon-6—is produced locally. Processing of thermoplastics is highly developed in both countries. Switzerland is recognized as the producer of excellent molding machines. Austria can rightfully boast of producing and selling the first all-plastics refrigerator.

THE FUTURE IN EUROPE

The greatest expansion in European plastics production over the next few years will be in the polyethylene field. Six plants are presently operating in Western Europe, and they will be joined by ten more in the next two years. Some increase in the production of PVC and polystyrene is expected, but in certain countries production of both these materials has already caught up with the demand. Since most of the pioneering plastics research is now devoted to the thermoplastics field, it can be expected that this group will be further enriched with innovations. In addition to thermoplastics, expansion is foreseen in the amino, alkyd and other thermosetting resins fields.

How far this rapid and successful progress in European plastics will develop depends on two factors: the continued recruiting of qualified technical and scientific personnel and the continuation of the present economic revival.

This continuing improvement in the standard of living can also be expected to result in a substantial increase in the per capita plastics consumption of Free Europe. During 1957, this amount was about 8.6 pounds against a comparable consumption of approximately 21 pounds per person in the United States. Some people believe and even predict that the standard of living in Europe will eventually approach the level prevalent in America. Should this prediction come true, it is conceivable that the plastics output of Free Europe could double or even treble during the next 10 years. Such an expansion in consumption and production will undoubtedly stimulate new developments and ideas in both materials and processing and make valuable contributions to the free world's plastics progress.

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Viscosity Conversion Nomograph

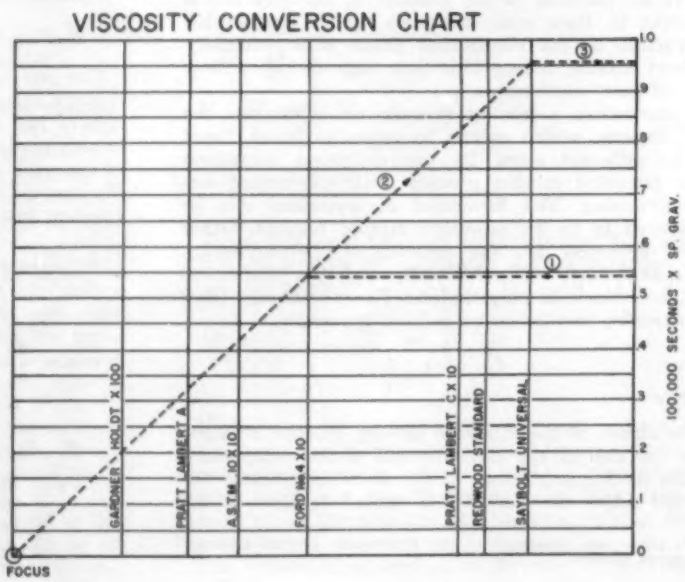
Jerome A. Seiner
Pittsburgh Plate Glass Company
Paint Research Department

IN ORDER to convert from one set of viscosity units to another, use the following steps:

1. Draw a horizontal through the number to be converted.
2. Connect original units intercept with focus and extend.
3. Draw a horizontal through the column with desired units.

Example

5,400 Ford #4 units = 95,200 Saybolt Universal units (*as shown by dotted lines.*)



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INTENSIVE MIXING

W. R. Bolen and R. E. Colwell
The Monsanto Chemical Co.
Plastics Div.

THERMOPLASTIC POLYMERS are processed in batch and continuous intensive mixers to produce combinations with various filters, colorants, and modifying ingredients. We will limit our consideration to a simple intensive mixer which with some modification is typical of the banbury, screw extruder, or the smooth surfaced torpedo.

Mixing which depends primarily on the degree of shear existing in the system is termed intensive mixing. Mixing which depends on the extent of flow or development of new surface is termed extensive mixing. Most theoretical studies of mixing have been limited to exclude the size reduction mechanism. Extensive particulate mixing is discussed by Lacey (Ref. 6) and Weidenbaum and Bonilla (Ref. 9). Several investigators have applied conventional statistical concepts to the extensive mixing process (Ref. 5) (Ref. 9). Mixing in laminar flow systems, again extensive mixing, has been described in two recent papers (Ref. 7), based on concepts presented earlier (Ref. 2).

Intensive mixing will usually be accompanied by extensive mixing simultaneously. We restrict our consideration here to a process in which intensive mixing is rate controlling. The mechanism of mixing is assumed to be the rupturing of individual particles in the discontinuous phase by a shearing stress developed in the continuous phase. The discontinuous phase is the filler, colorant, or other modifying ingredient to be mixed. When the shearing stress is greater than some threshold value (dependent upon the properties of the discontinuous components) there will be an increase in the number of particles and a reduction in their size. Materials which are soluble or miscible in the continuous phase will eventually (at long mixing times) lose their identity by a flow and diffusion mechanism.

In discussing a mixing process we often use the term disperse which means to cause to break apart and go different ways. By our definition dispersion is an intensive mixing process with concurrent extensive mixing. The formation of emulsions can be considered to be an intensive mixing process. Other typical examples are the coloring of thermoplastics, the manufacture of polyblends, and the dispersion of carbon black in polyethylene. Recent patents (Ref. 11) describe two intensive mixing processes.

Theory

The object of the intensive mixing process is to reduce the size of the discontinuous phase components by the mechanical action of the shearing stresses developed when the material is caused to flow in the mixer. A relation between the number of particles, the shearing stress, and the time of mixing is proposed. A method for estimating the shearing stress level in a simple intensive mixer is presented.

The mingling or distribution of particles randomly, throughout the system is not considered in this paper since we believe that adequate extensive mixing will be obtained concurrent with the generation of the sharing stresses required to cause particle rupture. The problem of extensive mixing is discussed in the literature (Ref. 7).

Mixing Index

$$M = \frac{(d_0 - d)}{d_0} \tag{1}$$

The mixing index, M, is a criterion of the accomplishment of the size reduction process in terms of the average size (volume average diameter) of the discontinuous phase component. d_0 is the initial particle diameter and d is the final particle diameter.

If the density of the particles is constant the number of particles varies inversely with the third power of their size.

$$\frac{n_0}{n} = \left(\frac{d}{d_0}\right)^3 \tag{2}$$

where n_0 = initial number of particles per unit volume
n = number of particles per unit volume after mixing.

Combining eqs. (1) and (2) we obtain

$$M = 1 - \left(\frac{n_0}{n}\right)^{1/3} \tag{3}$$

The rate of creation of new particles by mechanical rupture should depend upon the level of stress in excess of just that required to break the particle. Since mixing tends to approach and equilibrium state the rate of approach is apt to be an exponential function of time. We propose the following equation to relate the particle creation rate to shearing stress and time.

$$\frac{dn}{d\theta} = \frac{K\,(\overline{F} - \overline{F}_0)\,[1 - \exp.\,(-k\theta)]}{\overline{F}} \tag{4}$$

where, $\frac{dn}{d\theta}$ = change in number of particles with time
K = particle creation rate at high shear stress and long times
$\overline{F}$ = average shear stress
$\overline{F}_0$ = minimum shear stress to cause particle rupture
k = rate constant
θ = time

This paper was presented at the Fourteenth Annual Technical Conference of SPE.

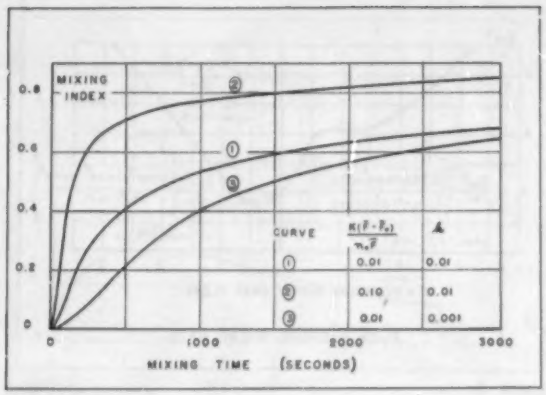

Figure 1.

When θ is large $\left(\text{greater than } \frac{5}{k}\right)$ the value of $\left(\frac{dn}{d\theta}\right)$ is approximately equal to $\frac{K\ (\overline{F} - \overline{F}_0)}{\overline{F}}$.

The percentage increase in the number of particles decreases rapidly even though the particle creation rate is constant.

An expression for the number of new particles formed can be obtained by integrating equation (4). For the case where K, $\overline{F}$, $\overline{F}_0$ and k are constant we obtain

$$\frac{n}{n_0} = 1 + K\,\frac{(\overline{F} - \overline{F}_0)}{n_0\, k\, \overline{F}}\left[\, k\,\theta - 1 + \text{exp. } (-\,k\,\theta)\right] \tag{5}$$

A relationship between the mixing index, M, and the parameters $\overline{F}$ and θ is obtained by combining equations (3) and (5). Typical curves of M vs. θ are shown in Figure 1.

$$M = 1 - 1 + \left[\frac{K\ (\overline{F} - \overline{F}_0)\,[k\,\theta - 1 + \text{exp. } (-\,k\,\theta)]}{n_0\, k\, \overline{F}}\right] \tag{6}$$

Basic Intensive Mixer

The elements of the basic intensive mixer are the surfaces between which the material to be mixed is contained. Mixing results from the action caused when one surface is moved with respect to the other surface. Projections from one of the surfaces may act as flow barriers and tend to provide a better heat transfer potential. The banbury type intensive mixer consists of two counter rotating shafts with integrally formed helical projections. Each shaft contains a length of right hand and length of left hand helical flight designed to pump material from each end of the mixer towards the center. An exchange of material between the rotors occurs in the nip region. The conventional extrusion screw has a much smaller helix angle than the banbury rotor, but otherwise the basic elements are the same. The smooth surfaced torpedo is a special case in which the rotating shaft has no projection.

If the material flow along the axis of the rotative shaft is sufficiently small compared to the flow in the direction of rotation, the system can be represented by a two-dimensional model as shown in Figure 2.

If the rotor is turned counterclockwise (moved to the left in the upper diagram) material tends to pile up at the left side of the barrier and a pressure P_2 is developed. At the right of barrier material tends to be dragged away and the pressure is less. Material tends to flow from the region of higher pressure to the region of lower pressure by two routes, over the top of the barrier and back through the space surrounding the rotor. We call these tip flows at the tip of the rotor and channel flows in the rest of the system. In each region there is a drag flow, caused by the relative motion of the surfaces, and a pressure flow due to the restriction of the drag flow in the channel by the barrier. The material balance, assuming the material to be non-compressible, is given by equation (7).

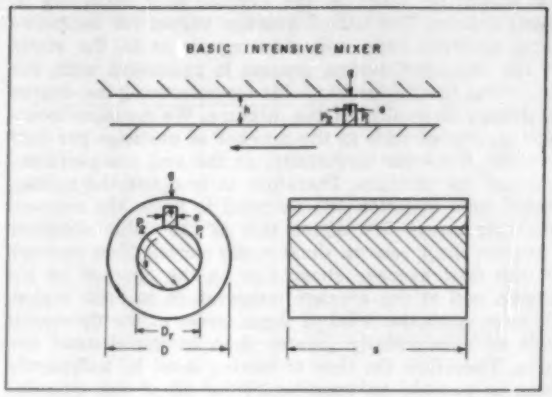

Figure 2.

$$Q_1 + Q_3 = Q_2 + Q_4 \tag{7}$$

where Q_1 = drag flow in channel
Q_2 = drag flow at tip
Q_3 = pressure flow in channel (direction is opposite to that of the other flows)
Q_4 = pressure flow at tip

The effect of entrance losses in going from the channel to the tip region has been neglected. A correction term depending on the length to clearance ratio could be determined using the method proposed by Bagley (Ref. 1). The drag and pressure flows in the basic intensive mixer pictured in Figure 2 are determined by the following equations.

$$Q_1 = \frac{\pi\, \overline{D}_c\, s\, h\, N}{2} \tag{8}$$

$$Q_2 = \frac{\pi\, \overline{D}_t\, s\, g\, N}{2} \tag{9}$$

$$Q_3 = \frac{-\,s\, h^3\ \Delta P}{12\ \pi \overline{D}_c\ \mu_c} \tag{10}$$

$$Q_4 = \frac{s\, g^3\, \Delta P}{12e\ \mu_t} \tag{11}$$

These relations, together with equation (7), can be combined to give an expression for the pressure drop across the barrier.

$$\Delta P = \frac{6\,\pi\, N\ (\overline{D}_c\, h - \overline{D}_t\, g)}{\left(\frac{h^3}{\pi\ \overline{D}_c\ \mu_c}\right) + \left(\frac{g^3}{e\ \mu_t}\right)} \tag{12}$$

If the material is Newtonian we need only specify the temperature in the channel and tip regions to determine the viscosity values μ_c and μ_t. Most thermoplastic melts are non-Newtonian, the flow response depending on temperature and shearing rate or shearing stress.

The values of μ_c and μ_t to be used in computing

ΔP should be based on the average flow occurring in these regions. The use of average values for temperature, shearing rate, and shearing stress in the study of the intensive mixing process is consistent with the analytical techniques available for measuring the degree of mixing or quality of the mixture. We measure average properties such as the number of particles per unit volume, the color uniformity, or the end use performance of the mixture. Therefore to compute the mixing index from equation (6) we need to know the average shearing stress. We define this as the value obtained from the shear rate vs. shear stress curves (flow curves) at the flow average shear rate in the channel or tip region and at the average temperature in each region. In most cases the level of shear stress in the tip region will be substantially greater than in the channel region. Therefore the time of mixing must be sufficiently long to provide an opportunity for all of the material to pass through the tip region at least once, otherwise the use of averages in characterizing the process is probably not justified.

The solution of equation (12) requires successive approximations since the shear rate depends on the flows induced by the pressure gradient. These calculations were programmed for computation on a IBM No. 702 Electronic Data Processing Machine. Shearing stresses in the channel and tip regions were computed for several rotor speeds, tip clearances, and material temperatures.

The flow average shear rate is obtained by weighting in proportion to the point velocity across the channel or tip region and is based on the simple isothermal Newtonian fluid velocity profiles. A plot of $\frac{\overline{G}\, s\, x^2}{Q}$ vs. f is given in Figure 3.

Flow Curve Correlation

The computational program selected required that the material flow curves (shear rate vs. shear stress vs. temperature) be expressed analytically. We decided to use an existing machine program to obtain a multiple regression correlation of the flow data. The apparent viscosity, μ, was correlated by the following equation.

$$\mu = a_0 \exp. [a_1X_1 + a_2X_2 + a_3X_1^2 + a_4X_1X_2 + a_5X_1^2X_2] \quad (16)$$

where,

$$X_1 = \log_{10} \frac{G}{G_0}$$

$$X_2 = \frac{T_0 - T}{T}$$

$a_0 = \mu$ when $T = T_0$ and $G = G_0$
$a_1, a_2, a_3, a_4, a_5,$ = correlation coefficients
G = shear rate
G_0 = reference shear rate
T = temperature
T_0 = reference temperature

The shear stress calculations in this paper are for a 0.914 g./cm.^{3} density, 2.1 melt index polyethylene. Flow curves for this material were obtained by Philippoff and Gaskins (Ref. 8). The following values for the coefficients in equation (16) were computed from their data.

$a_0 = 8.429$ # Force − sec/in.^{2}
$a_1 = -0.8588$
$a_2 = 14.4143$
$a_3 = -0.1291$
$a_4 = -0.9687$
$a_5 = -0.1647$
$G_0 = 0.1$ sec.$^{-1}$
$T_0 = 381$ °K

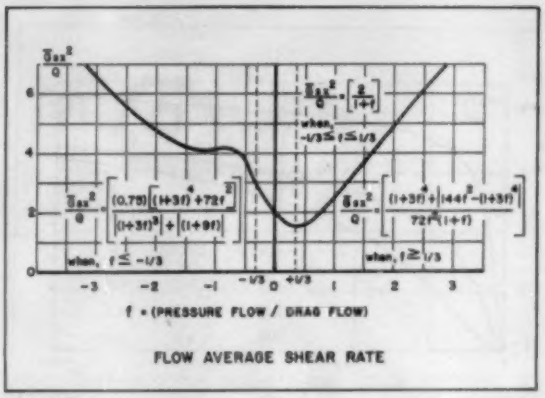

Figure 3.

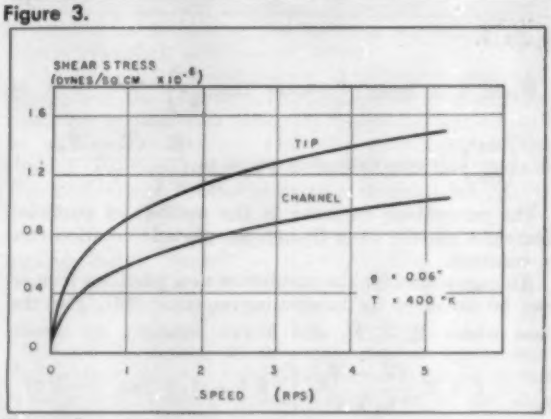

Figure 4.

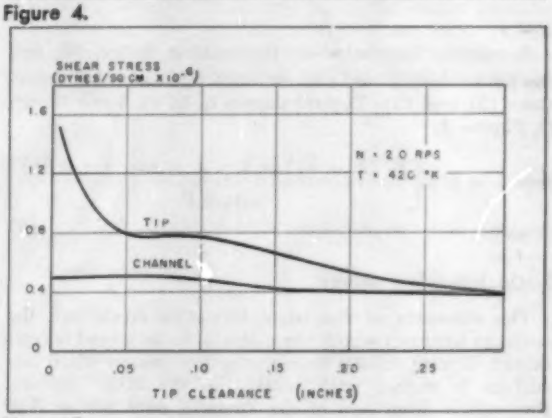

Figure 5.

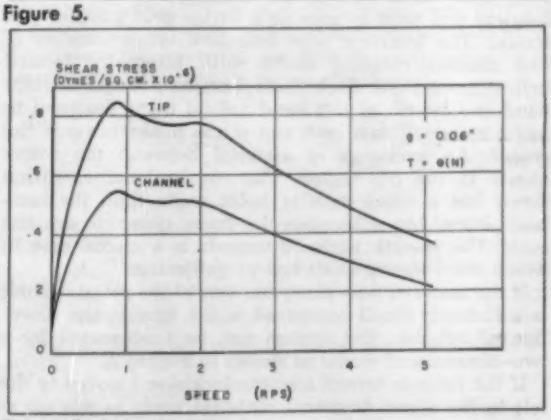

Figure 6.

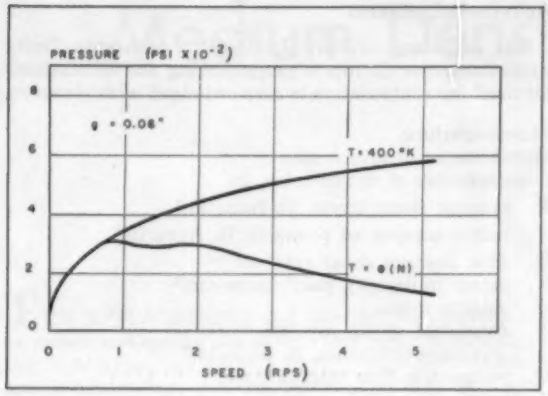

Figure 7.

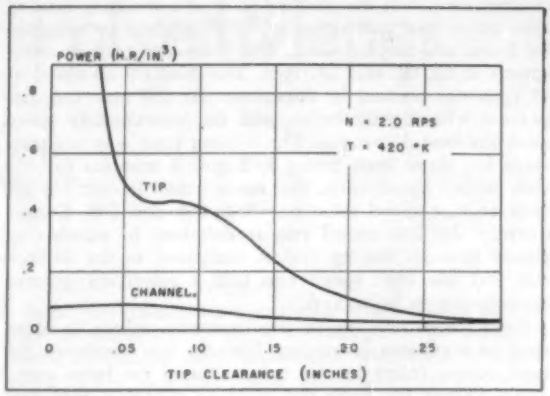

Figure 8.

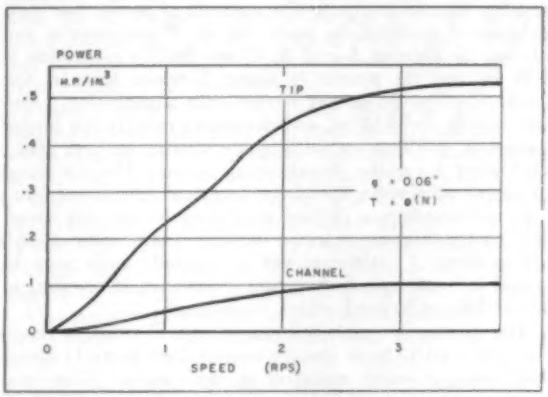

Figure 9.

The data were obtained between 108°C and 230°C and from low shear rates (1×10^{-4} sec.$^{-1}$) to about 1000 sec.$^{-1}$. The above correlation may be extrapolated to higher shear rates (10,000 sec.$^{-1}$), but extrapolation below G_o results in an appreciable error because of the form of the correlation used.

Average Shear Stress

The average shearing stresses in the characteristic regions of the basic intensive mixer are computed from the final values for μ and $\overline{G}$. The computation is started at arbitrary values for the flow average shear rates. A new estimate for the shear rate is obtained in each step and is used in the subsequent step. When the $(n + 1)$ value of shear rate is within 0.1% of the (n) value the machine is instructed to print out the results. The shearing stress is computed from the $(n + 1)$ values of μ and $\overline{G}$.

$$\overline{F}_o = \mu_o \overline{G}_o \quad (17)$$

$$\overline{F}_t = \mu_t \overline{G}_t \quad (18)$$

Typical results are plotted in Figures 4, 5 and 6.

Discussion

The computed results plotted are for a system of the following geometry:

D = diameter of mixer housing = 3.000 in.
Dr = diameter of mixer rotor = 2.125 in.
e = tip (barrier) width = 0.375 in.
s = length of mixer = 6.00 in.
h = channel depth = 0.437 in.

The major component of the material to be mixed is a 2.1 melt index polyethylene (Ref. 8) as previously noted. For these calculations we have assumed that the average temperature in the tip region is equal to the average temperature in the channel region. When the temperature varies with rotor speed the dependence is approximately hyperbolic.

$$T = a + b\sqrt{+N^2} \quad (19)$$

N = 0	1	2	3	4	rps
T = 400	405	420	440	460	°K

The pressure difference across the tip is plotted in Figure 7. The upper curve is for a constant temperature of 400°K. If the material were Newtonian and the process isothermal the ΔP curve would be linear with rotor speed. The reduction of the apparent viscosity with increasing shear rate tends to limit the magnitude of ΔP. The lower curve shows the more typical situation where the material temperature increases with increasing rotor speed. The two curves coincide at low speed since the temperatures are equal. Between 1 and 2 rps rotor speed the pressure drop levels at about 300 psi and at higher speeds it declines.

The average shear stress in the tip and channel regions is plotted in Figures 4, 5 and 6. The tip shear stress at constant temperature is about 40% greater than the shear stress in the channel. The shear rate in the tip region is about 3½ times greater than in the channel for the results shown in Figure 4.

The effect of varying the tip clearance is shown in Figure 5 for a rotor speed of 2 rps and a temperature of 420°K. For g between about 0.05 in. and 0.10 in. the tip shearing stress is almost constant. Actually there is a shallow minimum and maximum in this region. For other conditions of temperature and geometry these variations may be much greater. Below a tip clearance of 0.05 in. the shear stress increases rapidly. A problem of operating at small clearance levels is the necessity of extending the mixing cycle to insure that all of the material passes through the region of high shearing stress. The tip flows decrease quite rapidly with decreasing clearance. At large values of g the shearing stress in the channel and tip regions approach a constant value.

The tendency for the shearing stress to increase with increasing rotor speed is suppressed by the heating of the material due to viscous shearing. Typical results are shown in Figure 6. A plateau of shearing stress is obtained between N = 1 rps and N = 2 rps. This result

is consistent with the performance of a banbury mixing zinc oxide and unmasticated GRS rubber as reported by Jones and Snyder (Ref. 12). They ran tests at rotor speeds of 35, 69, and 137 rpm. The mixture obtained at 35 rpm was poorest in dispersion. At 137 rpm the dispersion was slightly better and the intermediate speed gave the best dispersion. The mixing time was not constant for these tests being 4, 3 and 2 minutes for the slow to fast speed runs. The rotor travel in feet for the slow to fast speed runs was 181, 267 and 348. Consequently the low speed run is deficient in number of passes through the tip region compared to the 69 rpm run and the high speed run had a relatively greater opportunity to be mixed.

Power consumption in the intensive mixer is often used as a criteria of mixing. Usually one measures the total power input to the rotors. Since we have computed values for both the average shearing rate and the average shearing stress in the tip and channel regions we can compute the amount of power per unit volume of material in each region. These results are plotted in Figures 8 and 9. When the tip clearance is 0.06 in. the tip power is about 5 times that in the channel. The tip power varies only slightly for g between 0.06 and 0.10 in. and decreases rapidly for larger values of g. This curve is quite similar to that given in Figure 5 for the tip shearing stress. The variation of power with rotor speed for a typical speed-temperature relationship is plotted in Figure 9. At low speed the power increases more rapidly than rotor speed. Up to about 2 rps the power is approximately proportional to rotor speed. A power maximum is reached at about 3.5 rps beyond which it declines.

The power per unit volume in the channel is much smaller than it is in the tip region. But there is about 150 times as much material in the channel. The total power consumed in the channel is therefore about 30 times that consumed at the tip. Only about 3% of the total power is dissipated in the tip region of the mixer. Consequently, it should be rather difficult, experimentally, to relate the variation in total power consumption to intensive mixing resulting from the high power per unit volume in the tip region of the mixer. One advantage of "master batching" is evident from these results and that is the increased efficiency in terms of total power input obtained by carrying out the intensive mixing process with the least volume of the major component. Dilution of the "master batch" to obtain the desired mixture is essentially an extensive mixing process which is carried out in the total volume of the mixer and may not require the high level of shearing stress necessary to produce good dispersion.

The extension of these concepts of intensive mixing to typical real equipment geometries is the next step in our work. It will be necessary to observe the performance of particular machines and to compare their performance in terms of pressure drop, power consumption, and mixing efficiency with the performance predicted from these calculations. Correction terms to compensate for end effects, complex flows in the nip region of the banbury, and axial flows resulting when the barrier is not oriented along the axis of the rotor should be developed.

The validity of equation (4) has not been established. It was proposed primarily as an introduction to the subject of intensive mixing in which the mechanism is one of size reduction. Since there are three adjustable constants (K, F_∞, and k) one should be able to correlate mixing quality characteristics adequately. The calculation of shearing stresses in the basic intensive mixer was the primary object of this paper.

Acknowledgements

The assistance of John Judd of the Monsanto Technical Computer Group in programming the calculations for machine computation is acknowledged with pleasure.

Nomenclature

D, diameter of mixer, in.
Dr, diameter of mixer rotor, in.
$\overline{F}$, average shear stress, lb. force/in.^{2}
$\overline{F}_\infty$, minor component property, lb. force/in.^{2}
$\overline{G}$, flow average shear rate, sec.$^{-1}$
K, factor in eq. (4), particles/sec.in.^{3}
M, mixing index
N, rotational speed, rev./sec.
ΔP, pressure difference, lb. force/in.^{2}
Q, volumetric flow rate, in.^{3}/sec.
T, temperature, °K
X_1, shear rate factor eq. (16)
X_2, temperature factor eq. (16)
a, constant in eq. (19)
a_o, a_1, a_2, a_3, a_4, a_5, correlation coefficients eq. (16)
b, constant in eq. (19)
d, volume average particle diameter, in.
e, width of barrier
f, ratio (pressure flow)/(drag flow)
g, clearance above barrier, in.
h, channel depth, in.
k, rate constant in eq. (4), sec.$^{-1}$
n, number of particles per unit volume, particles/in.^{3}
n_o, initial number of particles per unit volume, particles/in.^{3}
s, length of mixer, in.
x, thickness of flow, in.
μ, viscosity, lb. force-sec/in.^{2}
θ, time, sec.

Subscripts

c, refers to the channel region
t, refers to the tip region

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Medium Density Polyethylenes

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Spencer Chemical Co.

THE APPLICATIONS and uses of polyethylene are so varied and spread across so many types of industries that it is sometimes difficult to find common denominators of terminology that will be meaningful to all. To establish a better understanding it is important to consider medium density polyethylene, first, in terms of physical properties as they relate to processing characteristics, and secondly, in terms of end products and the markets for articles processed from medium density resins.

The high pressure or conventional process for producing polyethylene has, since the beginning, produced densities from 0.910 to about 0.925. These, of course, were the products produced under the original Imperial Chemical Industries patents beginnings in 1940 and continuing until about 1954. During that period the density (or the specific gravity, which is slightly higher) was seldom discussed, except to note the fact that polyethylene was the only commercially available plastics that was lighter than water.

Then, two years ago, it was announced that polyethylene with different properties could be produced at low pressures with new catalysts. The density of these resins run from about 0.941 to 0.965, and higher. Just last year it was learned that by modifying the existing high pressure process, a medium density resin could be produced with some properties intermediate between the other two materials.

The resins that were introduced during 1956, and which are the subject of this paper, fall in the density range of 0.926 to 0.940. Because of the confusion brought about by the sudden introduction of resins with many different densities, the ASTM has made an effort to define these terms. Figure 1 shows the density ranges with the proposed tentative limits applied by the ASTM. Thus, low density resins range from 0.910 to 0.925, medium density resins from 0.926 to 0.940, and high density resins from 0.941 to 0.965.

The physical properties of polyethylene do not change sharply at any of the numerical designations used to define low, medium or high density. That is, a resin with a density of 0.926 may be quite similar to a resin with a density of 0.925 although one could be called medium and the other low density. Instead of sharp changes, there are subtle and slight variations in some properties as density changes. But decided and definite property variations are apparent between lower and higher density materials when there is a difference in density of 3 or more units (0.003) in the third decimal place. Still other properties, such as permeability, change rather rapidly over a small density range and then remain almost constant. The medium density resins therefore, in some properties, will approximate or be similar to low density resins and other properties will be similar to linear polyethylene or high density resins. Still other properties fall exactly where you would expect them to—half way between the two extremes.

This paper was presented at the Regional Technical Conference of the Cleveland-Akron Section of SPE.

Melt index has been a property of interest to processors of polyethylene since its inception in the early 1940's. For many years the molder worked with a melt index of 1½ to 3 and, while occasionally he would use resins of slightly lower melt index, most of the resins with melt index less than 1 were generally associated with the electrical industry. During the past several years a wide range of melt indices have been offered to the molding industry, to film manufacturers, and to paper coaters and laminators.

Figure 2 shows the relationship of melt indices commonly marketed today in the three density ranges. The center bar shows that for lower densities of the medium range, melt indices as high as 30 are offered. However, as one advances towards a density of 0.940 the melt index gradually drops to a maximum of 4. It can generally be said that as the density increases, high melt indices become more difficult to provide. Specifically, as the density increases from 0.926 to 0.940 a number of undesirable properties develop in the resins made with high melt indices. For example, a resin with a density of approximately 0.935, when used in molded parts, loses considerable impact strength as the melt index is raised above 4. We also find that environment stress crack resistance degrades rapidly as melt index is increased. Figure 2 shows a minimum melt index of 1 for the medium density group. This has nothing to do with the ability of the resin suppliers to produce resins in this area, but indicates that at the moment there has been little demand, or even need, for them. It is expected that interest, need and demand will increase for such resins.

Generally, a molder is most interested in the melt index of a resin because it gives him considerable insight into the type of molding possible with the material, size of the mold, and the ease of molding. A resin with 0.935 density will require more pressure and/or higher temperatures to fill a mold originally designed for low density-high melt index polyethylenes. To the molder, this means that if he has a 16-ounce polyethylene mold and a 20-ounce press (rated in polystyrene) he would probably have to move the mold to his next larger press in order to produce a satisfactory part from a 0.935 density resin of melt index 4. However, if he has a little excess capacity in his 20-ounce press, because he is using a 14-ounce mold, then he will find that by raising his temperatures approximately 100°F, he will produce satisfactory parts without switching to another press.

While these samples may be extreme, the molder should be assured that satisfactory moldings can be produced with the lower melt index-medium density resin through the application of slightly higher heats and/or pressures than he would normally use with a low density resin of melt index 8 to 20. Similarly, a film manufacturer producing film from low density resins of melt index 2 at stock temperatures of approximately 350°F would find that very satisfactory film could be produced from a 0.935 density resin of melt index 4 in a tempera-

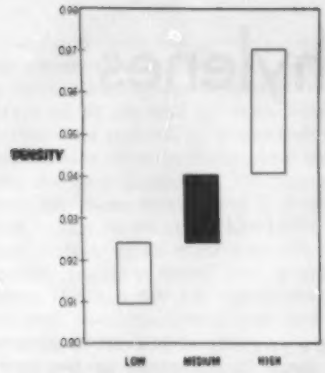

Figure 1. Density characteristics of polyethylene.

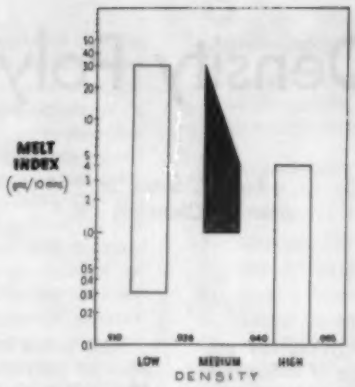

Figure 2. Melt index values of polyethylene.

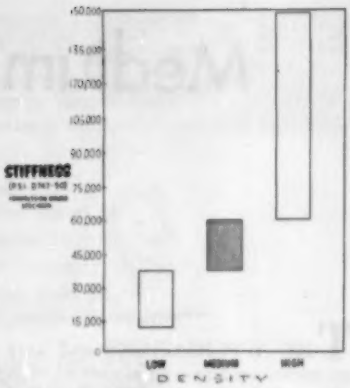

Figure 3. Stiffness values of polyethylene.

ture range of 350° to 375°F. Thus, temperatures must be raised about 25 to 50 degrees.

This same relationship would hold true for pipe, profile extrusions, and wire coating. It is interesting to note that where higher temperatures are used in extrusion operations, the required increase in temperature decreases. Thus, in some very high temperature applications, such as paper coating, where 600°F is common, resins with densities of 0.935 can be applied without any change in temperature.

Until the introduction of medium density resins, molders would ask what they could do about the waxy, rough-grained surface texture of low density polyethylenes. With the advent of these new resins unusually good surface gloss is possible. Generally, surface gloss improves as the density increases.

In a similar position there is still another important property. Figure 4 shows pictorially two wastebaskets produced in the same mold, one made with a low density resin of roughly 0.915 while the wastebasket that has no distortion was made from a resinof density 0.935. It should be remembered that molding conditions can have a significant and important effect on the stiffness of the end product, regardless of the resin employed, however low mold temperatures generally will effect the stiffness of the end product. Figure 3 shows that medium density polyethylenes have stiffness values of two to three times that of the low density polyethylenes. In this instance, stiffness varies in direct proportion to the density. The wide range of stiffness available in the high density resins over-shadows the relatively narrow ranges offered in either low density or medium density groups.

The stiffness of the medium density group has expanded the use for extruded polyethylene film to such trades as the textile industry where hand or crispness is important in merchandising to the retail trade. The advent of more rigid or stiffer materials has enabled the polyethylene film manufacturer to enter this same market. Likewise, the manufacturer finds it easier to insert merchandise into a bag which tends to hold its shape.

In terms of their market potential the significance of these improved handling properties was emphasized recently with the announcement that bakery equipment for bread overwrapping had been modified to use film produced from medium density resin.

Increased stiffness, coupled with higher tensile strengths, have made pipe with higher rated burst strengths available. Bottles can be made with thinner wall sections and still maintain the required strength, feel, and squeeze action.

While there are unquestioned advantages to increasing the stiffness properties for the molder and the extruder of film, bottles, or pipe, there are other problems. Generally, as the stiffness increases the resin and its resultant end product tend to become more brittle, and hence the impact strength decreases. It is possible, therefore, to get a polyethylene resin so stiff that it is no longer "unbreakable." Generally, impact strengths will vary as the density varies and, in this property, medium density material will have impact strengths intermediate between low and high density polyethylenes. This degradation of impact strength with increasing density is probably of greater significance to the extruder of polyethylene film than it is to the

Figure 4. Demonstrating stiffness of low (left) and high density polyethylene.

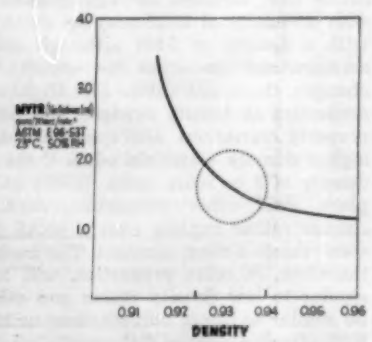

Figure 5. Density vs. moisture vapor transmission for 1 mil film.

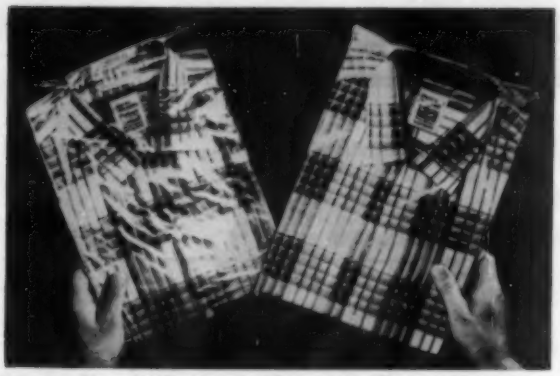

Figure 6. Clarity of medium density polyethylene film (right) is compared to films of low density resins.

injection molder. Our experience indicates that for general purpose packaging applications, the impact strength of medium density polyethylenes is at the point of diminishing returns. When working with medium density resins, the film manufacturer should pay special attention to the impact strength requirements.

Figure 6 illustrates one of the most important properties that has resulted from the development of the medium density resins. For many years, the manufacturers of polyethylene resins have struggled to improve the clarity of film resins to the point where merchandise wrapped and displayed in polyethylene would be attractive to the buyer. By methods generally used today for producing film, the clearest product is made from resins of the medium density range. Clarity is tied closely with surface gloss and haze. Haze approaches its minimum in the density range of 0.930 to 0.935, whereas surface gloss will continue to improve above 0.935. Thus, film clarity becomes a property which is not intermediate between low and high density, but which actually reaches its zenith in the medium density range. Both material suppliers and extruders are attempting to find other processing means which will enable production of clear films at higher densities. It is recognized that processing conditions, as well as special equipment, can have a very definite effect on clarity.

One of the properties of particular interest to the film manufacturer and the bottle maker and sometimes to the molder, is permeability. Figure 5 shows moisture vapor transmission for one mil film plotted against density. The dotted circle highlights the medium range. As density approaches 0.940 the moisture vapor transmission rate has decreased to a point where higher densities offer little advantage. Figure 7 shows density versus gas permeability for carbon dioxide and oxygen. Again we see that the major advantages of permeability are achieved within the medium density group, and little improvement in reduced permeability can be achieved above a density of 0.940. Figure 8 shows carbon tetrachloride permeability based on percent weight loss over a five week period when stored at room temperature in sealed bottles with an average wall of 40 mil thickness. The ability of the polyethylene bottle to contain the carbon tetrachloride with minimum loss increases rapidly as the density rises from 0.926 to 0.940 with relatively little improvement above 0.940.

During the past several years considerable headway has been made in the development of additives which impart a slip characteristic to polyethylene films, enabling two surfaces of polyethylene to slip easily over each other. More recently, resins have been introduced incorporating anti-block agents which keep the surfaces from sticking together. It is interesting to note that for the density range from 0.926 to 0.930, or slightly higher, control of slip and block characteristics through additives is a problem. However, at a density of 0.935 or above, the need for anti-block agents disappears entirely, apparently due to the increase of stiffness and faster set up of the resin. Slip agents can be added to impart low coefficients of friction, but generally are not used with resins of 0.935 or above. Thus, in the higher density areas of the medium density range, problems of slip and block are minimized to the point where it need not concern processing conditions.

By presently known and commonly used methods of extruding film, the low density resins have the best tear strength. Medium density resins show less resistance to tear, and if considerable care is not exercised in the extrusion of films, straight line tears or inherent weakness of the film will develop. This latter problem can be eliminated by the use of higher blow up ratios when producing blown film. Comparison of tear strengths between a low density resin of 0.915 and a medium density resin of 0.935 shows that the latter has ½ to 1/3 the tear strength in blown film of 1¼ mil thickness. These measurements are made by the Elmendorf test.

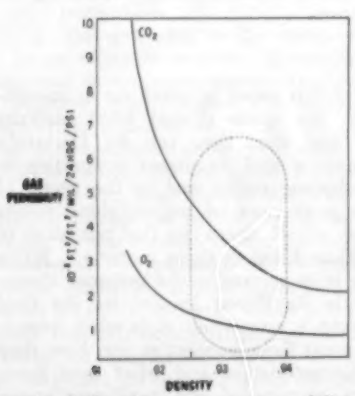

Figure 7. Density vs. gas permeability for polyethylene film.

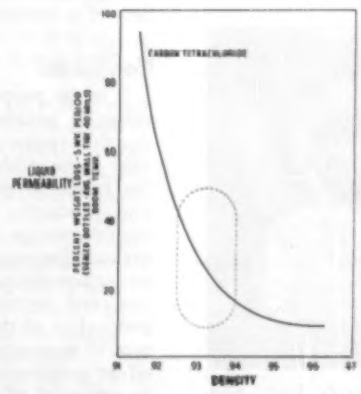

Figure 8. Density vs. liquid permeability for polyethylene film.

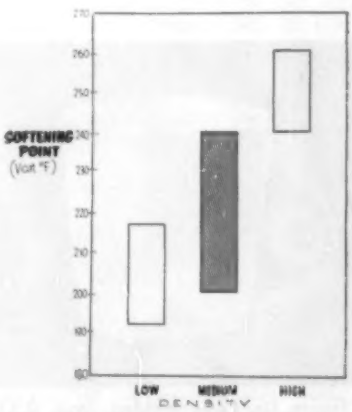

Figure. 9. Softening temperatures for various polyethylenes.

The final property deserving of mention is that of heat resistance. Figure 9 plots the range of Vicat softening points for the three ranges of densities. Note the wide spread of softening points between 0.926 and 0.940, with those resins between 0.935 and 0.940 showing considerable improvement over low density resins. Many of the medium density polyethylenes have softening points in excess of the boiling point of water which means that new use areas are available that were not heretofore available to the lower density resins. Figure 10 shows what was originally two molded cups, the one on the left being made from a 0.935 density, the one on the right from a 0.915 density. These cups were placed in a laboratory oven for 30 min. at 240° F. The result of this exposure to heat are quite evident. Evaluations of these resins for wire coating and jacketing applications are underway in uses where increased heat resistance is required.

The significant problem with any resin or group of resins is that of adapting the physical properties of any plastic material to the most efficient and most desirable end use application. Medium density materials have already found considerable use in injection molding for housewares, toys, and novelty moldings. Table I shows an analysis made by Spencer's Market Research Section indicating the use of polyethylene by density in the housewares field for 1953, 1956 and predicted for 1960. In 1956, five to ten million pounds of medium density resins were used in housewares, compared to a total of 50 million pounds. The report shows that by 1960 the medium density resins will take over a larger percentage of injection molded housewares.

Table II reflects the film market for the same three years. It can be seen for 1956 that the effect of medium density resins on the film market was relatively small. For 1960 it predicts that 50 to 75 million pounds will be used, even though we are just beginning to see a marked increase in interest and use of the medium density resins in this field. The medium density resins provide greater clarity and improved slip and block characteristics in films. They have opened up new potentials in soft goods packaging. The increased stiffness has already enabled a move into the overwrap field. The ability to draw down to half mil film and still have low permeability values will be an important factor in their growth. While these figures do not cover the paper coating and laminating industries, several manufacturers have found that it pays to use resins with densities of 0.930 to 0.935 in thinner coatings than they previously used with low density resins. This is true

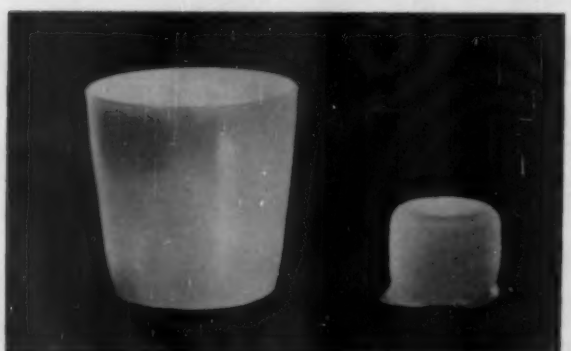

Figure 10. Cups molded from 0.935 density (left) and 0.915 density polyethylene after exposure to 240°F for 30 minutes.

TABLE I
Estimated Housewares Markets
(Millions of Pounds)

	Low Density	Medium Density	Low Plus Medium Density	High Density	Total - All Densities
1953	18	-	-	-	18
1956		5 - 10	47	3	50
1960		25 - 50	75	50	125

TABLE II
Estimated Film Markets
(Millions of Pounds)

	Low Density	Medium Density	Low Plus Medium Density	High Density	Total - All Densities
1953	45	-	-	-	45
1956		3 - 5	155	-	155
1960		50 - 75	300	40	340

TABLE III
Estimated Pipe Markets
(Millions of Pounds)

	Low Density	Medium Density	Low Plus Medium Density	High Density	Total - All Densities
1953	25	-	-	-	25
1956		less than 1	55	-	55
1960		10 - 20	85	20	105

despite the higher price on today's market for the medium density resins.

Table III reflects markets data in millions of pounds for extruded pipe. Here we find that in 1956 the use of medium density resin was negligible. However, we expect that by 1960 pipe manufacturers will find that the increased burst strength and improved heat resistance achieved with medium density resins—without the loss of "coilability"—will enable them to broaden their markets through increased applications. Already the use of medium density resins in the pipe field is growing.

As markets for this group of resins grow, identification and terminology will become more difficult. There are indications that resins in the medium density range will be manufactured by both the high pressure and low pressure processes. In some cases, these densities may be even be reached through blends of both types. While data are not complete, some differences are found in properties of a given density resin, depending on how it is manufactured.

Conclusion

It is the purpose of this paper to point out as specifically as possible in the space alloted what medium density resins are and what they can do. Certainly they have added unique and important properties to the range of polyethylene resins and to the scope of end products. The processors of polyethylene resins should remain alert at all times to the potential of making the most efficient use of these materials. While molecular structure is important to the polymer chemists, and certainly is significant insofar as the final properties of the resin is concerned, it is more important to understand what these properties are, how they effect processing characteristics, and what they mean in terms of efficient, economical and intelligent applications of polyethylene.

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Internal Strains in Casting Resins

New method for studying internal stresses provides design data for electronic embedments and makes possible the development of improved resin compositions.

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THE USE OF casting resins is now widely accepted by the electrical industry as being one of the best methods for protecting delicate electrical and electronic devices from damage by the elements and by physical abuse. Available on the market are scores of resins, hundreds of hardeners and catalysts, and a myriad fillers and additives. With so many materials available, the designer and the materials engineer have been severely burdened in their attempts to choose properly the materials for any new application. Little has been done in the field of investigation of possible synergistic effects of the ingredients of these potting compounds. Some tests are available such as the Hex-Bar test specified in MIL-C-16923A and the modified Hex-Bar test as described in the *SPE Journal*, Volume 12, #8, August, 1956. Unfortunately, however, such tests invariably yield only qualitative results, and no quantitative information about the stresses in a casting formulation is obtained. The purpose of this paper is to offer a test method which will yield quantitative information, thereby providing the materials engineer with a sound basis for the choice of constituents in a potting formulation.

Strain Gage Evaluation of Casting Resins

After a resin system is cast and cured, certain stresses become "frozen" into the body of the resin. These stresses are exerted on any embedded components and are a function of the following three factors:

1. The types of materials involved.
2. The environmental conditions—both past and present.
3. The geometry of the components involved.

In an effort to evaluate these effects, a test method utilizing strain gages was developed.

A strain gage consists of a length of very fine wire bonded to a laminate. In use, the gage is cemented to the test specimen under evaluation and thus strained uniformly with the test piece. As the gage is deformed, the cross sectional area of the wire is altered, thereby leading to changes in the resistance which are proportional to the applied strain. In this fashion the stress exerted on the specimen can be evaluated by electrical means. Such techniques have been used for years in stress analysis and test work but only recently have these methods been utilized by the materials engineer. It was thought that if a history of the stresses imposed on any cast component could be obtained by the use of such strain gages, the materials engineer could add greatly to his knowledge of the behavior of casting materials and processing techniques.

In the present test procedure, a Baldwin SR-4 strain gage type AB-7 with a ¼" gage length is cemented to the inside of a stainless steel tube. The tube is 1" in outside diameter, has a wall thickness of 0.035", and a length of 2" with the ends perpendicular to the tube axis. A stainless steel tube was chosen as the sensing element rather than some electronic component because metal tubes are accurate and sensitive to strains; they are unaffected by rapid changes of temperature and humidity; the simple cylindrical shape provides for symmetry of strain application; and they are much cheaper than assembled electronic devices. Three gages are mounted in the tube both circumferentially and axially. Two of the gages are mounted around the circumference 180° apart in the center of the tube and the other gage is positioned between these two in the direction of the axis of the tube. It is important to record the axial strains because hydrostatic pressure tends to distort the tube in this direction as well as circumferentially and the over-all effect of the stresses must be compensated for the axial distortion.

After the tube is prepared, it is carefully calibrated for the effects of temperature and pressure. A tube is calibrated for temperature effects by placing the sensing element in an oven and recording the strain readings at 10°C intervals from —80°C to 110°C. In this fashion, changes in the strain gage's resistance and thermal changes of the sensing element can be determined and used for strain compensation in the tests.

The tubes must also be calibrated for pressure. The sensing element is placed in a pressure chamber and the strains are recorded for hydrostatic pressures between 0 and 1000 psi, thereby enabling predictions of the strains due to tube distortion.

After the strain sensing element is calibrated, it is placed in a specially prepared mold consisting of a 2¾-inch diameter Teflon cylinder with a Teflon end-plate. Teflon is used because of the excellent release obtained with this material. A stud in the bottom of the strain sensing element is placed accurately into a hole in the center of the end-plate and tightened securely in place. The casting resin formulation under investigation is then poured in around the sensing element and up to the top level of the stainless steel tube. Two thermocouples are embedded in the resin, one against the side of the sensing element and the other

This paper was presented at the fourteenth Annual Technical Conference of SPE.

at a distance of 1" from the outside of the sensing element. These thermocouples establish the temperature gradient through the resin and indicate the temperature at which the strain readings are taken. The assembly is now ready to chart the behavior of the casting formulation as a function of any artificially applied environment. Figure 1 shows a close-up view of a casting ready for test. In operation, the strains induced upon the sensing element are carefully recorded and converted to stress measurements by use of simple mathematical formulas. In most cases the sensing element is subjected to compressive stresses because of the shrinkage factor of the polymers under consideration. However, in some isolated cases where the strains may not be uniformly distributed throughout the casting, the strain sensing element may indicate tensile stresses. Figure 2 shows a sketch of the casting prior to its removal from the mold.

Using the foregoing techniques, much information can be obtained on casting resins and casting techniques. A partial list of the information which may be derived by the use of this device is as follows:

1. A history of the stresses in the casting over a period of time.
2. The stresses developed during polymerization.
3. The effects of variations of curing temperatures and times.
4. Humidity and thermal effects.
5. Effects of vibration.
6. The behavior of different combinations of resins, hardeners, fillers, etc.

One of the most valuable uses of the strain sensing element is in studying the effects of thermal cycling of a casting system. Most electronic components are subjected to extremes of temperature, thereby greatly influencing their stress behavior and cracking resistance. The stresses reported in the following were obtained by thermally cycling the subject castings between 85°C and —75°C.

Flexible and Rigid Resins

A number of flexible resins are available for casting purposes. These resins vary in flexibility from rubber-like polymers to fairly rigid materials with low hardness values. Such resins are often chosen by resin compounders to avoid cracking of embedded components during temperature cycles involving low temperatures. Strain gage tests clearly indicate the differences between rigid and flexible polymers. Figure 3 shows a graph of an extremely rigid casting composition (Selectron 5003 filled with silica) and two flexible casting resins (Acme Star 2002 and Scotchcast 235-M). Note how the curve for the rigid resin rises in a fairly uniform manner to a substantial stress with very little change in temperature. Such stress curves are characteristic of most rigid materials. In contrast to this type of behavior are the flexible resin systems shown directly below the first line. It can be seen that the flexible resins have a much lower slope and it is not until a comparatively low temperature is reached before any stress at all is exerted on the tubes. It can be seen that at —40°C the rigid resin exerts a stress of 2400 psi while the flexible materials exert only a stress of about 1200 psi, a difference of 1200 psi!

In general, these curves exemplify the differences between rigid and flexible casting materials. The rigid materials give fairly straight line relationships in the temperature ranges under consideration and reach stresses in excess of 1000 psi at temperatures as low as 30°C. The flexible systems, on the other hand, do not give straight lines until the resins become rigid.

Figure 1. Close-up view of a casting ready for test.

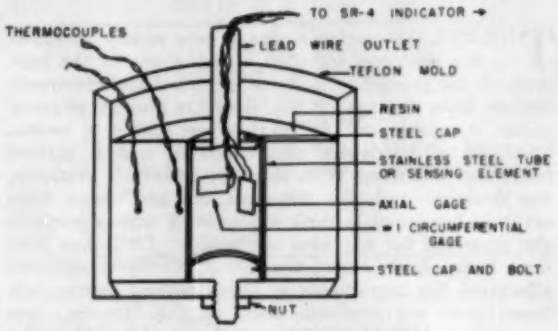

Figure 2. Cutaway view showing tube potted in resin.

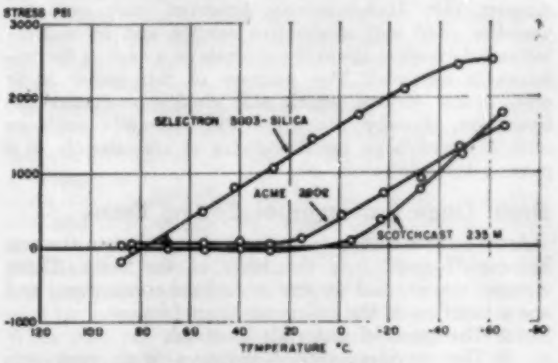

Figure 3. Comparison of flexible and rigid resins.

At temperatures above 20°C the resins often put the sensing element under tension.

The Effect of the Addition of Reactive Diluents

Flexible epoxy resins often possess flexibility as a result of the addition by the manufacturer of reactive diluents to a more rigid polymer. Another purpose of adding reactive diluents is that their addition generally reduces the viscosity of the system. In order to evaluate the effects of the addition of such materials, a study was made of the stress changes induced by the incorporation of styrene oxide and glycidyl phenyl ether into Epon 828 with a piperidine curing agent. The results are shown in Figure 4. The top curve on the graph is for the unmodified epoxy. Phenyl glycidyl ether added to this epoxy decreases the stress at any temperature without altering the slope excessively. On the other hand, styrene oxide still further decreases the

stress and a small change in the slope can be noticed. Thus, it would indicate that the addition of either of these two reactive diluents make for more flexibility and substantially decrease the stresses on an included component.

It should be noted that the addition of such reactive diluents causes other changes in a casting system as well as reducing the viscosity of the resin system and the stresses in the casting. The physical properties of these modified resins are usually reduced. In particular, notch sensitivity is greatly increased and the heat distortion point is substantially reduced.

The Effect of Hardener on Epoxy Resins

The choice of an epoxy hardener is very important. Indeed, hardeners often determine the properties of the resin composition. Accordingly a study was made of the effect of two hardeners on Epi-Rez 507. The formulation was held constant except for the choice of hardeners.

Figure 5 gives the results of this test graphically. It can be seen that with this formulation, curing agent Z imparts a higher stress at all temperatures than curing agent D. For example, at 0°C the stress using curing agent Z is 1000 psi, whereas the stress from curing agent D is only 500 psi. The advantages of being able to measure the effect of a change in a hardener system is obvious for it enables the compounder to tailor his compositions to his needs within the limitations of other requirements. It can be mentioned that alterations in the catalyst system of polyester resins appear to have little or no effect. Two different catalysts may cure polyesters at different rates, but the final stress on a fully cured component is virtually the same no matter which catalyst is chosen.

The Effect of Curing Temperature and Time

It has been often found that the curing temperature and the time taken to cure epoxy resins influence the end product. This is confirmed by the following experiments, results for which are given in Figure 6. The same epoxy resin, the same hardener and the same filler system were used with two different curing schedules. The upper curve is a record of the stresses on the sensing element when this formulation was cured for two hours at 150°F and then two more hours at 200°F. The results for this same formulation cured for four hours at 150°F are given by the lower curve. These data clearly indicate that resins cured at lower temperatures usually have lower stresses.

The phenomena involved in the cracking of a resin composition can also be observed from these curves. Note that at a temperature of —50° how each of the curves suddenly change slope rapidly. At this temperature each of these castings cracked, suddenly relieving the stresses. In some cases after the casting has cracked, the stress again begin to build up after having been redistributed through the uncracked sections of the casting.

Summary

A new technique for investigating and evaluating casting compositions is described in this paper. The method involves the recording of internal stresses in a casting formulation by use of a specially designed strain sensing device. The data presented should be useful to compounders as well as users of casting formulations. Design information can be obtained which will permit wider latitude of choice of materials in the embedment of electronic equipment. The resin chemist should also find a useful tool in this device to correlate stresses with molecular structure, thereby making possible the synthesis of improved polymers. In short, the method provides a new tool for studying internal stresses in casting resin compositions which should help make possible the development of improved resin compositions for various potting, encapsulation and embedment applications.

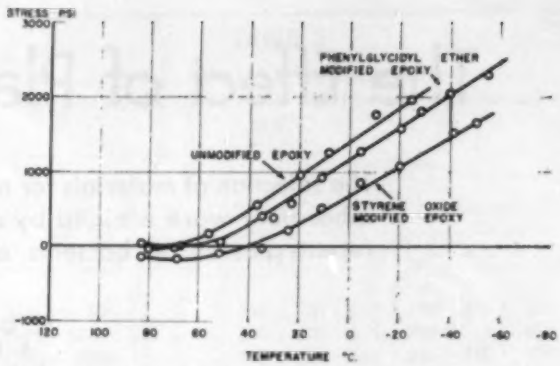

Figure 4. Effect of reactive diluents.

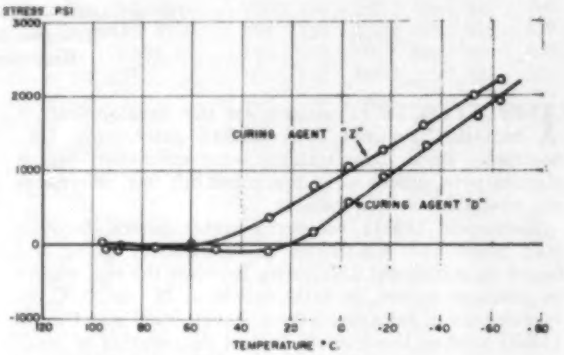

Figure 5. Effect of hardener.

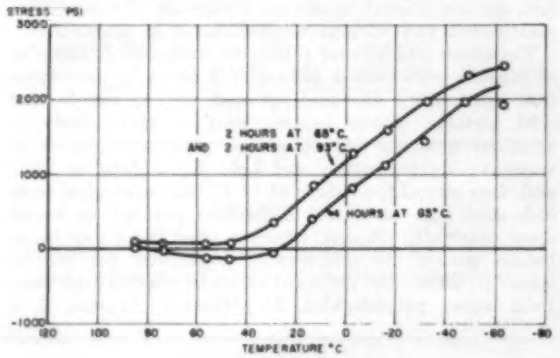

Figure 6. Effect of curing temperature.

Acknowledgements

A number of people contributed to the present paper and while it would be impossible to list them all, the authors would like to acknowledge the assistance of A. Bush for his excellent stress analysis and R. G. Black for his help in obtaining the data.

★ ★ ★

The Effect of Plastics on Bacteria

The selection of materials for milk sample containers and other laboratory ware is aided by a study of the effects of 23 different plastics on bacteria commonly encountered in milk.

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THE EFFECTS of plastics on the development of bacteria have not been studied extensively. Undoubtedly some investigations were conducted before plastics petri dishes were marketed but few references are available on this subject.

Mackenzie (1951) compared water passed through lead pipes and Alkathene (polyethylene) pipes and found no significant differences between the two waters in coliform counts, in total counts at 22° or 37°C, or in numbers of actinomycetes or fungi. Stahl and Pessen (1953) studied the microbiological degradation of plasticizers. *Aspergillus versicolor* and *Pseudomonas aeruginosa* were found to utilize, as the sole source of carbon, certain dialkyl sebacates, a number of commercial plasticizers and various alcohols used in plasticizers.

Tiedeman and Milone (1955) investigated 22 samples of plastics pipe over a period of 3 years to determine their suitability for underground use in conducting cold, potable water. In one part of their study, a weighed quantity of segmented pipe was placed in water in Pyrex bottles and held for 3 days at 35°C and then stored for 9 days at 10°C. Bacteriological tests indicated that 70 to 160 organisms per ml. of water were originally present, whereas after the 3 day incubation period the numbers of organisms per ml. of water in which the different types of plastics had been held were: polyethylene, 2; polyvinyl chloride, 2; a mixture of polyethylene and polyvinyl chloride, 4; cellulose acetate butyrate, 19,000; and rubber modified polystyrene, 1,700,000. These same water samples showed no significant change in bacterial counts after refrigerated storage for 9 days. Similar water without plastics had a bacterial count of 2 at the start, a count of 1 after 3 days and also after 9 days. The authors suggest that materials from certain plastics may leach into the water providing nutrients for microbial growth.

Zytel, a nylon resin produced by DuPont, was subjected to bacteriological testing by an independent commercial laboratory (U. S. Testing Co., Inc., 1956). Pasteurized milk stored in the presence of bars of this nylon showed no significant change in bacterial numbers when compared with controls.

The present study was undertaken to determine whether plastics were inhibitory to bacteria commonly encountered in milk. The question of toxicity arose when it was proposed to develop an inexpensive, single service plastics bag and catheter for collecting milk samples directly from udders and shipping to a laboratory for bacteriological testing.

Materials and Methods

Twenty-three different plastics materials in pellet or powder form were furnished by nine manufacturers. A list of the specific materials is given in Table 3.

TABLE 1

Number of organisms per ml. in inoculated fresh whole milk containing various concentrations of Super Dylan 6200 after different periods of holding at 9°C

Inoculation	Plated After	Per Cent of Plastics Added to Inoculated Milk		
		5%	10%	20%
	hr			
Micrococcus pyogenes var. *aureus*	0	5,600	9,000	5,000
	6	4,700	6,500	7,300
	24	13,000	10,000	13,000
Streptococcus sp.	0	2,400	2,400	2,800
	6	3,200	3,400	3,200
	24	4,600	4,500	5,500

TABLE 2

Number of organisms per ml. in inoculated fresh whole milk containing various concentrations of Teflon after different periods of storage

Inoculation	Plated After Storage*	Per Cent of Plastics Added to Inoculated Milk			
		0%	5%	10%	20%
	hr				
Micrococcus pyogenes var. *aureus*	0	320	240	250	690
	24	750	5,800	5,900	6,400
	48	1,000	3,700	9,700	9,000
Streptococcus sp.	0	34	63	62	80
	24	740	2,000	3,300	2,600
	48	1,000	15,000	25,000	—

*Stored at 9°C.

Reprinted from Applied Microbiology, Vol. 6, No. 2, March 1958.

Bacteriological plate counts were made using M-P H medium (BBL). All plates were incubated at 35°C for 48 hours before observing or counting. Laboratory cultures of *Escherichia coli* and a coagulase positive strain of *Micrococcus pyogenes* var. *aureus* were employed for preliminary studies. In other phases of the investigation a strain of streptococcus and a culture of *M. pyogenes* var. *aureus*, isolated from milk from infected bovine udders, were included to determine the effect of plastics on such organisms. To further test this point, abnormal milk from an udder with teats damaged by freezing was mixed with plastics and the microflora studied.

Results

The first test performed was to determine the effect of autoclaving different plastics in the presence of M-P H agar and the subsequent effect of this medium on two cultures of bacteria. Fifteen plastics were selected and 1.0, 2.5, and 5.0 g, respectively, of each were added to bottles containing 100 ml. of agar and then sterilized. Duplicate sets of plates were poured making certain that none of the plastics was carried over into the petri dishes. One set of plates was streaked with *M. pyogenes* var. *aureus* and the other set with *E. coli*. After incubation bacterial growth on control plates containing agar which had been sterilized without plastics was compared with growth on plates that had plastics in the medium during autoclaving. The growth on all plates was comparable indicating that under the conditions tested none of the plastics exhibited a toxic effect.

The second experiment was designed similarly to that employed for testing antibiotics with sensitivity discs. Petri dishes were poured with M-P H agar inoculated with *M. pyogenes* var. *aureus* and *E. coli*, respectively. Before the agar had completely hardened five pellets or an equivalent amount of powdered plastics were grouped together. In this way five different plastics were tested on each plate. After incubation no zone of inhibition was noted around any of the plastics, and the amount of growth on all plates, including those without plastics, was comparable.

Super Dylan 6200 polyethylene was selected to determine its effect on *M. pyogenes* var. *aureus* and a streptococcus. These cultures were isolated from milk from abnormal udders. Since it was originally proposed to develop a plastics bag for milk samples, flasks of fresh whole milk were inoculated with the micrococcus and the streptococcus respectively. Fifty ml. portions of milk were added to milk dilution bottles containing 2.5 g, 5.0 g, and 10.0 g respectively of the plastics. To simulate field conditions of refrigerating samples while shipping to a laboratory, the bottles were held at 9°C and plate counts were made after 0, 6, and 24 hr.

The findings (Table 1) indicate that Super Dylan in concentrations as high as 20% had no inhibitory effect on the bacterial population in the milk while being held for 24 hr. at 9°C.

A similar run was made using the molding powder Teflon (tetrafluoroethylene resin) and an inoculum as large as might be encountered in heavily contaminated milk. The milk samples were held at 9°C for 48 hours before the final plating. The results shown in Table 2 indicate that there was no inhibitory action on the inoculated micrococcus or streptococcus by this material. In fact, there was generally a greater increase in bacterial numbers when the test organisms were in contact with the plastic than when they were in milk alone.

(*Continued on page 54*)

TABLE 3

Numbers of organisms per ml. in inoculated fresh whole milk plus various plastics after different periods of storing at 9°C

Material	Inoculation					
	Micrococcus pyogenes var. *aureus*			*Streptococcus* sp.		
	0 hr	24 hr	48 hr	0 hr	24 hr	48 hr
	Thousands					
Marlex 50	140	160	370	180	380	480
Geon 870	140	170	200	200	750	460
Dylan 3900	150	160	160	220	340	550
Super Dylan 6200	140	190	160	180	340	580
Plexiglas V-100	190	220	140	250	430	440
Plexiglas VM-100	200	190	200	200	310	590
Bakelite VGG 1100	190	150	230	220	440	550
Bakelite DYNH-1	170	180	200	240	390	410
Geon 103 EP	190	180	160	270	330	330
Zytel 42	200	200	180	300	550	750
Zytel 101	200	2800	180	310	580	370
Zytel 31	140	190	570	260	370	680
Kel-F	170	500	160	280	290	610
Alathon	180	200	210	230	400	540
Teflon	150	370	170	270	390	460
Styrex 767	250	170	180	310	560	610
Styron 475	120	160	190	230	500	620
Styron 666	160	190	150	240	450	540
Saran 281	210	230	240	280	320	400
Ethocel R21	150	190	190	300	340	520
Tenite butyrate 201 A	180	120	210	300	400	540
Tenite butyrate 205 A	230	180	170	190	380	690
Tenite butyrate 454 A	130	210	210	330	430	450
Control (No plastics)	150	200	170	160	380	410

TABLE 4

Numbers of organisms per ml. in milk from injured udder plus representative plastics after different periods of storing at 9°C

Material	Standard Plate Count			Standard Plate Count on Blood Agar			Hemolytic Count on Blood Agar		
	0 hr	24 hr	48 hr	0 hr	24 hr	48 hr	0 hr	24 hr	48 hr
	Thousands								
1. Marlex*	17	12	14	16	13	14	9.4	7.6	9.3
3. Geon	13	7.2	12	9.9	11	12	7.7	6	8.6
5. Super Dylan	15	15	14	16	13	14	8.6	11	9.6
7. Plexiglas	15	17	14	15	15	15	9.4	9	11
8. Bakelite	14	14	14	11	16	16	6.6	9	10
14. Teflon	14	14	15	15	11	14	11	7	9.2
15. Kel-F	13	15	17	15	16	18	9.5	9	11
19. Saran	17	7.9	10	11	7.5	11	6.5	4	7.2
21. Tenite	15	17	15	18	14	16	7.3	6	11
Control (No plastics)	15	16	16	16	12	15	9.7	8	9.8

*See text.

Edited by Louis Paggi, *Consultant, E. I. du Pont de Nemours & Co., Inc.*

New Designs of Injection Molding Machines

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The Injection System

A most important part of the injection molding machine is the injection end, consisting of the heating chamber, the feed mechanism and the injection hydraulic system. The design and control of these components have a considerable effect on the quality of the molded part and materially assist in maintaining cycle economy. The part produced should meet all requirements with respect to appearance, physical properties, stress concentration and dimensions. The contribution of the molding machine to the successful molding of such a part will involve precise control of heating, pressure, weighing and speed.

We can all agree that many variables are involved in the molding process and anything that we can do to improve the control of these variables will benefit the industry.

The modern machine is equipped with more precise controls than were formerly available.

For example, today we make use of a multiple pump system with flexibility in control over the hydraulic fluid delivery. This system employs one or more high volume pumps and one low volume pump. This type of system will allow injection at an extremely high rate of speed over the entire injection portion of the cycle, coupled with the ability to hold pressure with the low volume pump after the shot is made. It will also make it possible to inject a portion of the shot at high speed followed by slow filling to complete the shot. This change in rate of filling is accomplished by using the delivery from the high volume and low volume pump or from the low volume pump only. Selection of delivery is controlled by a timer having an accuracy of 1/60 of a second. Precise timer control over the rate of fill will permit better quality production of moldings such as toilet seats, screw driver handles, shoe heels and certain decorative heavy-section acrylic parts. A comparison of the daul speed and the conventional single system is illustrated in Figure 1.

In addition to the dual and controlled rate-of-fill system, a dual and controlled pressure system is also provided. The same timer mentioned above is utilized to cut in the secondary pressure setting of the injection system. For example, any given portion of a shot may be filled at high pressure with the balance of the shot filled at low pressure or partly filled at low pressure and completed at high pressure. This performance is illustrated in Figure 2. With a conventional single pressure system the entire injection portion of the cycle would have to be performed only at the maximum pressure setting of the pump thus limiting the flexibility necessary for certain types of moldings.

This dual system can be easily adapted for use with the device which measures pressure at the nozzle and in the mold. Instead of controlling the high pressure by a timer it would be possible to control it by the pressure developed at the nozzle or mold. When the pressure builds up to a predetermined level, the high volume pump is cut out automatically and the injection pressure is reduced to a lower predetermined setting. This arrangement makes it possible to maintain uniform shot-to-shot pressure thereby contributing to good quality production. It also makes it possible to mold shots having a greater projected area without causing the clamp to yield.

Material Feeding

Perhaps the greatest single advancement in the molding operation, in recent years, has been weigh feeding. The modern weigh feeder

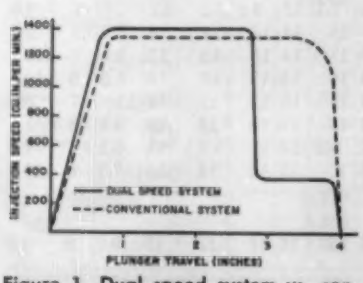


Figure 1. Dual speed system vs. conventional system.

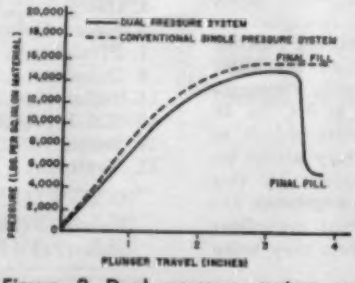


Figure 2. Dual pressure system vs. single pressure system.

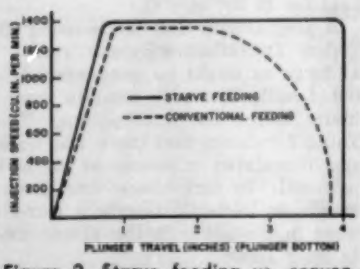


Figure 3. Starve feeding vs. conventional feeding.

will accurately weigh the material and will also compensate, maintaining a constant weight of charge in event of failure or interruption of other machine components. The weigh feeder is installed with two micro-switches mounted on an adjustable track. If the operation requires "starved" feeding (the exact amount of material necessary to fill the mold) the adjustable track is positioned to allow one switch to be contacted only in the event the plunger should bottom. When this switch is contacted a compensator is cut into the circuit which causes a second charge to be dropped into the weigh bucket. This compensating second charge, coupled with the first will equal the exact weight required for a complete shot. Should the plunger not complete its entire stroke, the limit switch will not be contacted and the compensating portion of the charge will not be fed. The second micro-switch is utilized to discharge the weigh bucket into the feed part of the plastifying cylinder. This switch is positioned to prevent discharging the weigh bucket before the major portion of the shot is taken. In this way excessive loading of the feed port of the cylinder, such as would occur in the event the entire shot could not be discharged into the mold, would be avoided.

Another advantage, that of permitting a faster rate of injection, is illustrated in Figure 3. In a mechanical compensating type of feed, the accuracy of the feed charge cannot be as closely controlled, therefore it is necessary to maintain a "cushion" or over feed of material in front of the plunger. If we are to avoid flashing, the pressure applied to the material during injection can be no greater than that which can be supported by the clamping force. With shots having a large projected area, the injection pressure permissible will be limited. With weigh feeding, the "cushion" of material can be eliminated. This removes the limitation on the pressure which can be applied on the material since when the ram has completed its stroke, the injection pressure is transferred to the mechanical stop in the hydraulic cylinder. The higher pressure permissible with weigh feeding will also result in a faster rate of injection.

If necessary the weigh feeder can also be adjusted to overfeed every other charge. This also provides a very accurate feeding arrangement which automatically compensates and stays in the same relative position.

Preplastifiers

Preplastifying machines make use of a separate heating chamber to plastify material before it is placed in front of the injection ram for introduction into the mold. This type machine, when suitably applied, offers many advantages to the molder. Among the advantages are:

1. The ability to take heavier unit shots.
2. More uniformly heated material.
3. Better quality parts.
4. More uniform pressure in the mold.
5. Higher pressure available to the mold.
6. Less pressure loss in the shooting cylinder, therefore the mold may be filled with lower temperature material thus contributing to cycle economy.
7. Faster rate of injection. This is made possible because of more efficient use of pressure and because the density of molten material is at least twice as great as that of the granular. In this connection it should be recognized that injection speed should not be measured on the basis of linear inches per minute of ram travel but rather of cubic inches per minute of molten material fed to the mold.

The disadvantages of preplastifiers are:

1. The machines are more complex and therefore, require personnel with better training.
2. They cannot be profitably used with short run jobs.
3. Color and material changes will require an estimated 50% more material than on conventional machines. Changes will require approximately ¾ to one hour of unproductive time.

The disadvantages, however, are insignificant when a preplastifier is used in its proper application.

After years of working with preplastifiers we are completely sold on their merit and are in the process of introducing a new and improved design.

Clamping Device

The importance of good design in the clamping end of the machine should not be minimized. In addition to the requirement of sufficient clamping force to keep the mold closed, we must also provide for ease of mold set-up, adequate and adjustable clamp stroke, adjustable slow down for mold breakaway and ejection, and adjustable clamp pressure.

Production Speed

The true speed of production of molded parts can only be measured by the actual number of acceptable parts produced per unit time. This means that the speed of the machine as measured when performing a cycle must also be matched by availability of molten material to fill the mold and the quality of the molded part produced.

We are concerned with speed because of its implication on economy. We should therefore look at economy over a projected period of time. When this is done, some of the factors to be considered are:

(a) The speed at which a mold can be set up.
(b) The rugged and dependable performance of the machine.
(c) Adequate clamp capacity for large projected areas or large number of cavities.
(d) Flexibility to handle a wide variety of molds and molded parts.

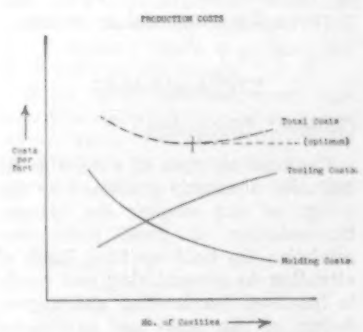
★ ★ ★

Errata . . .

Two errors were made in Molding Cycles in the July *Journal*. On page 33, column 2, the equation should read:

$$x = \sqrt{16.7} = 4 \text{ cavities}$$

The graph on page 32 was included by mistake. The correct Figure 1 is shown at right:



—*Editor*

SPEAKING OF EXTRUSION

Edited by R. D. Sackett
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Monsanto Chemical Company
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Streamlining of Extrusion Dies

P. N. Richardson

Sales Service Laboratory
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E. I. du Pont de Nemours & Co.

IT IS NOT surprising in our industry which is moving very rapidly that we have just not taken the time to write down some of our know how. This is especially true in the field of extruder die design (K. O. Robbins, *Modern Plastics*, December, 1955). It is the purpose of this discussion to summarize some of our experiences concerning streamlining of extrusion dies. Many of the newer synthetic resins are more heat sensitive than the older resins and for this reason more attention has to be given to the design of die parts.

Two factors, time and temperature, govern the stability of a resin in an extruder. Both too long a hold up time and too high a temperature can degrade most resins. It is the time factor with which this discussion is concerned. However, we believe that heating and control of temperature is of equal importance for successful extrusion.

STREAMLINING

General Discussion

The hold up time of a resin in an extruder is largely governed by the design of the adapter die system. Streamlining of these parts can minimize the hold up time. Lack of attention to streamlining can result in localized overheating and degradation of the resin and can make purging and color changes very difficult, if not impossible.

It is well known that the resin in the center of a die moves at a faster rate than that at the wall. This is readily observed during color changes. Actually the velocity profile across a tube is parabolic (J. P. Tordella, *SPE Journal*, May 1953).

From flow theory it is possible to calculate the velocity and output of the resin in any portion of simple dies. The following values are given to show how comparatively slow the resin moves near the wall in a tube.

Let us consider the thin donut of resin flowing within the outer 5% of the radius of a circular die. This outer portion represents 10% of the volume of the die, but the resin flowing within this outer portion accounts for only 1% of the output from the die. In other terms the velocity of the resin at a distance of 5% from the wall to the center is only 10% of that at the center of the die.

What does all this mean with respect to streamlining? First of all there is a distribution of hold up times within the die, even the perfectly streamlined die. The material near the wall is in the die a great deal longer than the material in the center of the die. Therefore, any obstructions to the flow of the plastic near the wall can slow down the flow still more or stop it altogether. Streamlining can eliminate these problems. Second, it is suggested that dies and adaptors be built as small as possible. Smaller diameters and shorter lengths will help to keep the walls swept clean and will minimize the hold up time. Third, tubes with changing diameter require special attention to streamlining. The diameter change may be increasing or decreasing and both require streamlining. Figures 1 and 2 show complete non-streamlining for both cases. These show pictorially the flow pattern of the material as well as the dead spots.

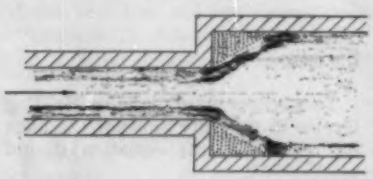

Figure 1.

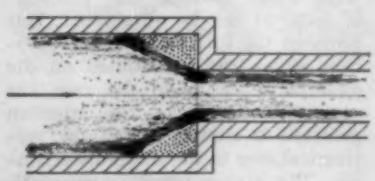

Figure 2.

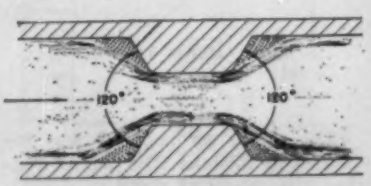

Figure 3.

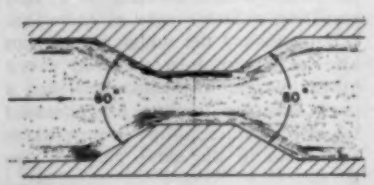

Figure 4.

Part Design

So far we have considered the general need for streamlining as dictated by the nature of viscous flow. In the following section specific parts will be discussed which effect the flow of the resin and if not properly designed can act as hold up spots.

Adaptors

How should exits and entrances be designed? They must be tapered to accommodate the natural flow of the material. A 120° included angle is not sufficient but a 60° included angle gives good performance. These are shown in Figures 3 and 4. Again, these are pictorial sketches of flow and hold-up areas.

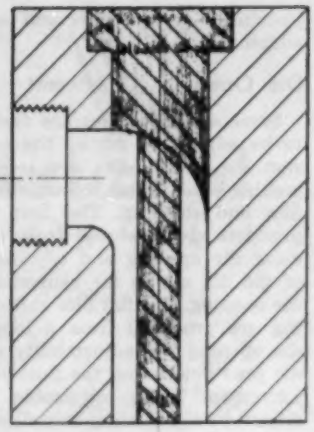

Figure 5.

Bends

Very similarly, square corners should be avoided in bends. Crosshead and off-set pipe and tubing dies are examples of dies with bends. A smoothly contoured wall should be provided for the flow of the resin around the mandrel. (Figure 5). A similar situation exists at the end of sheeting or flat film dies. The end plate should be contoured to accommodate the flow of the resin and thus avoid a dead corner (Figure 6).

The Extruder Screw

The very end of the screw can be a dead spot. If the end of the screw is flat, the polymer at the center can just turn around for the ride. For this reason the ends of screws should be tapered or rounded.

Breaker Plates

The function of the breaker plate is to act as a sealing surface between the die adaptor and the extruder, to break up the spiral flow resulting from the screw, and to support screens if desired. The breaker plate should not act as a hold-up area for resin. Figures 7, 8 and 9 show breaker plates of improper design.

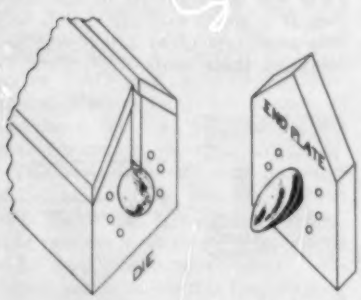

Figure 6.

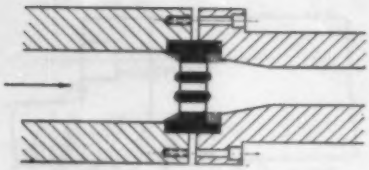

Figure 7.

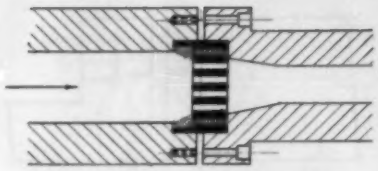

Figure 8.

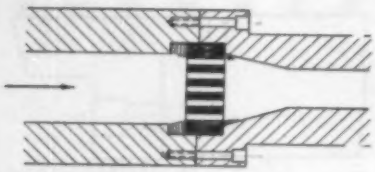

Figure 9.

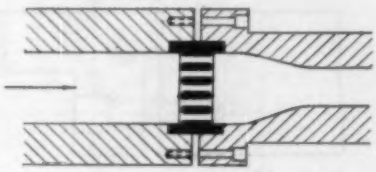

Figure 10.

In Figure 7 the holes are not close enough to the edge. This provides a dead ring around both sides of the breaker plate. In addition, the holes in this breaker plate are too large. Large holes also mean large areas between holes and the areas between the holes are dead areas. In Figure 8 the diameter of the sealing surface of the breaker plate is not the same as that of the extruder and the die adaptor. Also in this case there are dead-ended holes in the breaker plate. Figure 9 shows a loose breaker plate which does not act as a sealing surface. In addition to having a hold-up spot this equipment probably will leak.

Figure 10 shows a breaker plate which is of good design. It is made about ⅛" longer than necessary to provide for a definite sealing surface and for easy maintenance. The sealing surfaces should be smooth and true. With this extra length the sealing surface can be turned down in a lathe many times and the breaker plate will still be long enough to act as a seal. Both the rear and the front ends of the breaker plate are provided with sealing surfaces protruding from the hole area. It is designed this way for maintenance. The sealing surfaces can be cleaned up without the necessity of turning down the whole breaker plate. The holes in the breaker plate are small (1/8" to 5/32"). All of the holes are countersunk on both ends to eliminate dead areas, and as many holes as possible are used. Special attention is given to the outside ring of holes. These should be as near as possible to the edge.

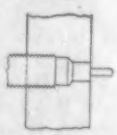

Figure 11.

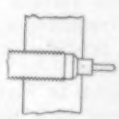

Figure 12.

Thermocouple and Pressure Gauge Locations

It is often useful to measure the temperature and the pressure of the resin in the die. A description of the equipment for doing this is reported in a paper by E. C. Bernhardt (*SPE Journal*, November 1955). It is necessary to provide holes for these thermocouples, or gages, and careful attention should be given to their location. Figure 11 shows an ideal seating of such a device and Figures 12, 13 and 14 show several improper seatings. Figure 12 shows a thermocouple seating flush on a flat surface. The joint is smooth and no place is provided for hold-up.

In Figure 12 the thermocouple is sticking out too far. That means there is a greater obstruction than necessary in the melt stream. In Figure 13 the opposite is true. The thermocouple assembly does not fit far enough into the wall. This leaves a pocket in which resin can cook and decompose.

Figure 14 shows the thermocouple coming in at an angle and not sitting squarely on the inside surface. This also leaves a dead pocket.

Frequently, such holes have been made on conical surfaces. This, in general, is poor practice because the hole on a conical surface is an odd shape. In machining such holes they are frequently made too large, and dead pockets are caused.

Holes for thermocouples are sometimes located on a die in a spot where there is a very heavy wall. In this case we have found it good practice not to thread the full

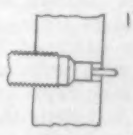

Figure 13.

Figure 14.

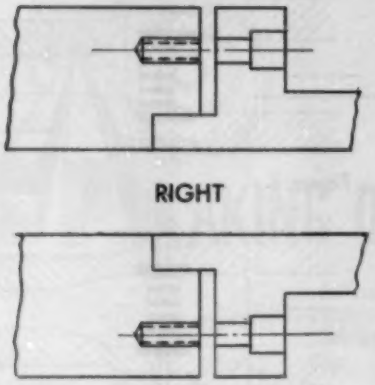

Figure 15.

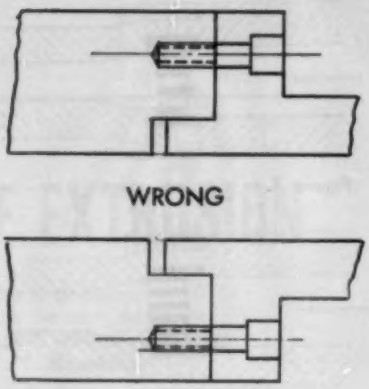

Figure 16.

length of the hole, but only the bottom ½" to ¾". This prevents needless wear of the threads.

Seals

It is not uncommon to find dies, adaptors and gates which leak. A small leak does not concern most people, but they are real trouble when dealing with heat sensitive materials. A leak usually represents a hold-up spot as a leak passage is not streamlined. Resin in the small cracks decomposes and the decomposition products find their way back into the melt stream. The following description gives a few ideas on designing tight systems.

It is necessary to have an extrusion die tight while hot but it is not necessary that it be tight when cold. For this reason the die should be tightened after it has been heated and before the extrusion run has started. In the design of the die and adaptors all bolts used in tightening should be exposed and available. No bolts should be covered by other parts.

It is essential that all sealing surfaces be smooth and true. Sealing surfaces must meet properly and should not be obstructed from meeting by other parts. Under the description of breaker plates it was suggested that sealing surfaces be designed with extra length for maintenance purposes. This is shown again in Figures 15 and 16. If the die is designed with the ideas of Figure 15 in mind, the situation of Figure 16 can be prevented. In this latter case the surfaces which are supposed to seal do not touch.

Unless seals are tightened by a proper procedure, even parts which seat perfectly will leak. Bolts on the opposite sides of a bolt circle should be tightened alternately, and a pattern should be established for tightening the bolts. This is done to prevent cocking the parts by tightening one side at a time. This is especially important when attaching heavy dies to the extruder. The weight of the die may fool the person tightening the bolts.

It is good practice not to cover seals with heater bands. If a seal is covered a leak cannot be discovered as soon and the situation corrected.

Gaskets

Sometimes a gasket is used to improve the seal between the die and the extruder. In general a gasket is a rather poor substitute for proper equipment. A gasket is a crutch and should be used only as an emergency measure. Probably the worst feature about gaskets is the lack of attention which is given to the fit of the gasket. They are seldom cut to the right size and thus, they usually provide hold-up areas and dead pockets. The best designed die will not function properly when used with a poorly fitted gasket.

Leveling Adjustment

For many extrusion operations it is necessary that the die be leveled. In order to prevent leakage the leveling arrangement should be made independent of the sealing mechanism. Unfortunately, this has not always been the case and frequently a threaded adaptor is used both for sealing and leveling alignment. With this equipment the die may be aligned but usually it is not sealed.

Alignment adjustment is provided on the end of many extruder barrels with various clamp ring and gate arrangements, but it is also easy to provide for this using a bolted clamp ring. Such an adaptor is shown in Figure 17. In this system there is a tightly sealed threaded joint and complete alignment adjustability at the other end of the adaptor.

Die Opening Adjustment

Some extrusion dies are designed to be adjustable during the extrusion run. Such dies are used for making pipe, tubing, blown film flat film and sheeting. The first three products are produced from a circular die opening and adjustability of the die allows for centering the die opening. The flat film and sheeting are produced from a long flat die opening and adjustability of the die jaws determines the thickness of extrudate. These adjustable parts should be tight fitting as well as adjustable.

For extruding heat sensitive materials the die should be leak-proof first and adjustable second. In some cases this may mean loosening the seals before adjustments can be made and then tightening the seals again.

The only design suggestion that can be offered is to use large size bolts for adjustment so that they can be moved even if the die is sealed quite tightly.

STANDARDIZATION

Long range planning should be used in the design of equipment. Standardization of dies and adaptors will permit interchangeability among different machines. With standardization it is possible to stock fewer spare parts. There are many items upon which it is possible to standardize without limiting flexibility. Bolts and heater band sizes are two of them. Others would be breaker plates, adaptors and clamp rings. Standardization also insures uniform design with respect to items of streamlining. Non-standard pieces of equipment frequently lead to rush jobs to which careful attention is not given.

Without a doubt those of us working in the field of extrusion believe in having control of the die temperature, in streamlined parts and in versatility of extrusion dies. It is hoped that this article will help stimulate ideas which will accomplish these ends.

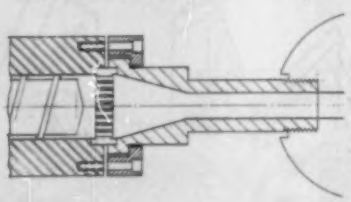

Figure 17.

★ ★ ★

National Action—

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The New SPE Journal—1958 Model

Although the *Journal* is already the outstanding technical publication in the realm of plastics engineering and science, the unrelenting work of the Publications Committee is focused on strengthening this position and forging ahead into areas of greater service. Improvement of *Journal* technical content is the primary goal which directs the planning and activities of the present Publications Committee.

The Committee points with pride to the quality of the *Journal's* technical papers and the technical features "Molding Cycles" and "SPEaking of Extrusion," and holds equal expectations for new features being instituted. Benefits are twofold—higher technical quality and direct participation of more members in the *Journal*.

New Features

To supplement the fine work of Louis Paggi and Robert Sackett in their features on injection molding and extrusion, the Publications Committee has approved the establishment of a feature on polymer science. It has appointed as Editor Dr. Irvin Wolock of the U. S. Naval Research Laboratory and the Baltimore-Washington Section. This feature will soon make its first regular appearance in the *Journal*. Other technical areas represented by large, active PAG groups such as reinforced plastics will be themes of additional features planned for the near future.

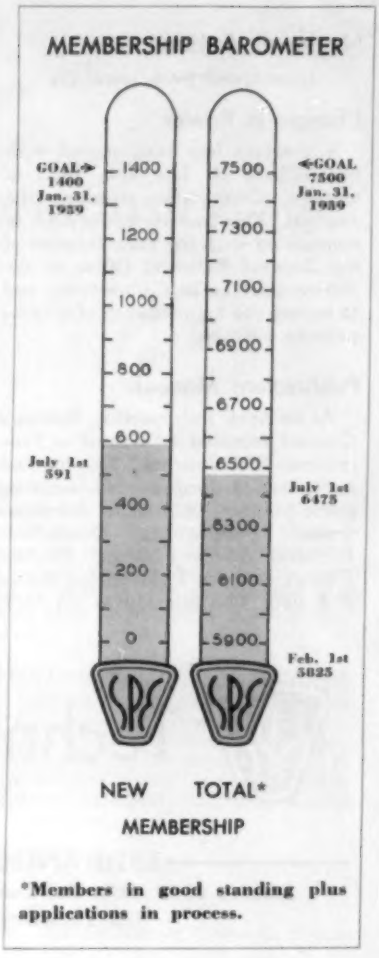
The June issue marked the start of two new regular features. "About SPE Members" is designed to provide readers with news of members and their accomplishments. Although material for this feature may be gleaned from any source, the main responsibility for information for these items lies in the hands of Section News Reporters.

Another duty of the Section News Reporters is to provide complete and accurate information for the new monthly feature "SPE Technical Meetings Calendar." To serve members properly, these meeting notices should include forthcoming Section meeting information such as time and place of meeting, name of technical speaker and subject of talk. Section News Reporters now have the additional responsibility of inviting outstanding speakers at Section meetings to prepare their talks for possible publication in the *Journal*. These functions, plus the increased emphasis on all Sections reporting each month, encourage greater participation of Section News Reporters in the *Journal*.

Editorial Advisory Board

The Society's Editorial Advisory Board has been expanded to include members who are experts in technical fields not previously covered by the Board. Now numbering 16, the Board includes technical authorities from the various segments of plastics science and engineering. New members are: Dr. Luther Bolstad, Minneapolis-Honeywell Corp.; Benjamin S. Collins, Nopco Chemical Co.; and Fred Wehmer, General Adhesives Co. They bring to the Board specialized knowledge on epoxies, urethanes, and adhesives, respectively.

Members of the Board continuing their services to the *Journal* are: Chairman, Gordon B. Thayer, Dow Chemical Co.; Dr. Russell B. Akin, E. I. du Pont de Nemours & Co., Inc.; Robert W. Barber, St. Regis Paper Co.; Edward F. Borro, Sr., Durez Plastics Div., Hooker Chemical Corp.; William Croll, The Hydraulic Press Mfg. Co., Inc.; Russell M. Houghton, Conap Co.; John P. Lombardi, Shaw Insulator Co.; Jules Pinsky, Plax Corp.; Dr. Frank W. Reinhart, National Bureau of Standards; Robert D. Sackett, Monsanto Chemical Co.; Edward W. Vaill, Bakelite Co.; Quentin M. White, F. J. Stokes Corp.; and Donald R. Williams, Chippewa Plastics Co. The Society owes a considerable debt to these men.



*Members in good standing plus applications in process.

Expanded Staff

Dr. Jesse H. Day, who for many years has devoted himself to the improvement and growth of the *Journal*, has been elevated to the position of Editor Emeritus, and will continue as an active member of the staff. In addition, the full-time efforts of a new editor and editorial assistant will permit the *Journal* to function in line with its expanding editorial requirements.

(*Continued on page* 44)

National Action . . .

(*Continued from page 43*)

Change in Printer

A contract has been signed with the Wilson H. Lee Co., Inc., of Orange, Conn., for printing the *Journal*. This move was made in connection with the consolidation of the *Journal* Editorial Office in the National Office in Connecticut, and to assure the maintenance of a competitive position.

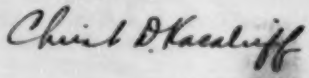
Publications Manual

At its April 15th meeting, National Council accepted a "Manual of Procedures, SPE Journal." This manual serves as a long-needed working guide for the Publications Administrator, Publications Committee, Editorial Advisory Board, Feature Editors and the Publications Editor and staff. The procedures set forth represent the best thinking of present and past Publications Committees and staff. It is intended that the manual be reviewed by each succeeding Publications Committee to insure that it is consistent with the growth of the Society and its technical publications.

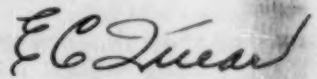
Circulation

There has been an increase in *Journal* circulation of about 13% during the past year, from 6,974 in June 1957 to 7,875 in June 1958. However, the Publication Committee is intensifying its efforts to show greater gains in this aspect of *Journal* operations. It has started an aggressive circulation campaign directed at public and company libraries, educational institutions and other organizations.

Another major increase in circulation will result from the excellent promotion program in progress by the Membership Committee, under the Chairmanship of Frank W. Reynolds, National Councilman from the Binghamton Section. This Committee expects to gain 1,400 new members by January 31, 1959, with the aid of the Section Membership Committees and it's powerful new tool—the Membership Brochure.



Christ D. Kacalieff,
Administrator
Publications Committee



Eugene C. Quear,
Chairman
Publications Committee

Technical Meetings Calendar

15TH ANTEC

January 27-30, 1959, The Commodore Hotel, New York City

1958 RETECS

Plastics in the Automotive Industry

September 12, 1958, St. Clair Inn, Detroit, Mich.

For information write to John D. Young, E. I. du Pont de Nemours & Co., Inc., 13000 W. Seven Mile Rd., Detroit, Mich., or R. C. Oglesby, Rohm & Haas Co., The Nor-Way Bldg., 20211 Greenfield Rd. at Jas. Couzens Hwy., Detroit 35, Mich.

Plastics in Packaging

October 1, 1958, Statler Hotel, Hartford, Conn.

For information write to Blakely McNeill, Fuller Brush Co., 3580 Main St., Hartford 15, Conn.

Epoxies

October 21, 1958, Curtis Hotel, Minneapolis, Minn.

For information write to Russ Kirby, Minnesota Mining and Manufacturing Co., 900 Farquier, St. Paul, Minn.

Plastics in Electronics

October 24, 1958, Stanford Research Institute, Menlo Park, Calif.

For information write to Julius W. Palen, c/o Lenkurt Electric Co., Inc., San Carlos, Calif.

Advances in Injection Molding

November 6, 1958, Sheraton Hotel, Philadelphia, Pa.

For information write to Edward Fitzpatrick, F. J. Stokes Machine Co., Olney Post Office, Philadelphia, Pa.

Plastics Trends in Building and Construction

November 13, 1958, Ambassador Hotel, Los Angeles, Calif.

For information write to John Delmonte, Furane Plastics, Inc., 4516 Brazil St., Los Angeles, Calif.

1959 RETECS

(*Scheduled before June 1959*)

Plastics in the Shoe Industry

April 21, 1959, St. Louis, Mo.

For information write to Robert S. McDorman, Plastics Molding Co., 4211 N. Broadway, St. Louis, Mo.

Plastics in the Metal Industry

May 7, 1959, Penn-Sheraton Hotel, Pittsburgh, Pa.

For information write to John Parks, Hydraulic Press Manufacturing Co., 512 Empire Bldg., Pittsburgh 22, Pa.

SECTION MEETINGS

Northwestern Pennsylvania

September 25, 1958, Sportsmen's Athletic Club, Erie, Pa.

THE URANIUM INDUSTRY will be the subject of a talk and movie presented by Robert J. Klatzbach, manager, chemical processes, Union Carbide Nuclear Co., Div., Union Carbide Corp., New York, N.Y. Dinner is at 7:15 PM, and the program is at 8:30 PM.

RETEC

Regional Technical Conference:

Plastics for the Automotive Industry

Sponsored by the Detroit Section
St. Clair Inn and Country Club, St. Clair, Mich.
September 12 and 13, 1958

Friday, September 12

9:00 A.M.—Registration, St. Clair Inn

Morning Session

Moderator—J. T. O'Reilly, *Assistant Manager, Process Development Dept., Ford Motor Co.*

10:00 A.M.—"Automotive Stylists Look to Thermoplastic Materials for New Interiors"—T. R. Grimes, *Sales Manager, Royalite Div., U. S. Rubber Co.*

This report on current automotive applications of acrylonitrile-butadiene-styrene type thermoplastic sheets, both flexible and rigid, includes domestic and foreign cars. Topics covered are physical properties, surface finishes, forming and assembly techniques, and styling.

10:30 A.M.—"Polyester Premix Potpourri"—Owen Pelham, *Director of Research, Woodall Industries.*

This paper will be a brief refresher on the present-day technology of compounding, manufacture and use of premix molding materials for the automotive field. It will discuss the need for industry-wide material acceptance procedures.

11:00 A.M.—"Advances in Automotive Lighting—Plastic Lenses"—A. Meyers, Jr., *Administrative Assistant to the Chief Engineer, Bay City Div., Electric-Auto-Lite Co.*

This discussion of exterior and interior automotive lighting covers the progress made in the past ten years with the help of plastics. Design possibilities, tooling and safety factors are discussed.

11:30 A.M.—"Vacuum Metalizing in the Automotive Industry"—William Pahl, *Manufacturing Research Engineer, Ford Motor Co.*

Several decorative and functional applications of first-surface vacuum metalizing in automobiles will be discussed. Topics include design requirements, materials, processing, properties and future potential.

12:30 P.M.—Conference Luncheon, St. Clair Inn
Aims and Accomplishments of SPE
R. K. Gossett, *National President*
T. A. Bissell, *Executive Secretary*

Afternoon Session

Moderator—William Gobeille, *Manager, Plastics Div., American Motors Corp.*

2:00 P.M.—"Advances in Compression Molding of Automotive Parts"—B. J. Bonkowski, *Process Engineer,* and T. H. Meister, *Senior Materials Engineer, Hardware & Accessory Div., Ford Motor Co.*

This paper reviews and highlights some of the unique phases of semi-automatic molding of thermosetting materials as is currently being done at Ford Motor Co.

2:30 P.M.—"Plastics for Manufacturing Equipment and Tooling Aids"—William Ervin, *Supervisor, Plastic Tooling Laboratory, Delco-Remy Div., General Motors Corp.*

Machine parts and tooling aids made from plastics tooling at Delco-Remy include transfer boxes, gears, cams, and arbors. Parts will be demonstrated. Comparative costs and performance data on parts made from steel and plastics tooling will be discussed.

3:00 P.M.—Panel on "More Plastics in Automobiles—How?"—J. R. Forrester, *Junior Principal Research Engineer, Research Div., Ford Motor Co.;* C. James Rawson, *Assistant Manager, Organic Materials Laboratory, Chrysler Corp.;* Robert Waters, *Senior Materials Engineer, G.M. Truck & Coach Div., General Motors Corp.;* L. E. Horodyski, *Purchasing Agent, AC Spark Plug Div., General Motors Corp.*

6:00 P.M.—Cocktail Party, St. Clair Inn

7:00 P.M.—Dinner, St. Clair Inn
Welcoming Address—Malcolm Nichols, *President, Detroit Section, SPE*
Principal Address—"Periscoping Plastics Potential Posterity"—M. F. Garwood, *Chief Engineer, Engineering Div., Materials, Chrysler Corp.*

Saturday, September 13

9:00 A.M. to 5:00 P.M.—Golf at St. Clair River Country Club; Swimming, Boating, Fishing

The Annual Fall Golf Outing—Detroit Section, SPE—will be held in conjunction with the Conference. Detroit Section members will vie for the Silver Bowl Golf Trophy for low gross golfer.

6:30 P.M.—Cocktail Party, St. Clair River Country Club

7:30 P.M.—Dinner and Dance (Dancing to the music of Verne Willard and his orchestra)

RETEC Committee

Co-Chairmen: R. C. Oglesby, *Rohm & Haas Co.;* J. D. Young, *E. I. du Pont de Nemours & Co., Inc.* Registration: J. Donalds, *Dow Chemical Co.* Treasurer: R. Filippelli, *B. L. Maas Associates.* House Committee, J. Kuhn, *Wolverine Plastics.* Printing: F. S. Marra, *Detroit Mold Engineering Co.* Publicity, S. Shiefman, *Shiefman & Associates.*

ABOUT SPE MEMBERS

Dr. Jesse H. Day, Editor Emeritus of the SPE Journal, has been promoted to the status of full professor at Ohio University. This follows his recent promotion to head of the Chemistry Department. Dr. Day is a member of the Central Ohio Section of SPE.

Leslie J. Shehan, Secretary of SPE's Ontario Section, has left for New Delhi, India, where he will be assigned to the Technical Assistance Administration of the United Nations. Working through the Indian Government, he will advise the Indian plastics industry on the design and manufacture of molds. He has been given a year's leave of absence by his company, Canadian General Electric Co., Ltd. **Edgar P. Newman** of Atlas Powder Co., Ltd., has been appointed Section Secretary in Mr. Shehan's place.

L. J. Shehan

J. K. Honish

John K. Honish has been appointed market analyst on the staff of the market research department of Bakelite Co. His duties will include the economic, market and technical aspects of vinyl resins and compounds. Mr. Honish, a member of the Newark Section, was formerly assistant manager of the product engineering department, and has been with Bakelite for more than 25 years. He serves as consultant to the Department of Commerce and is chairman of the Building Research Institute. He is also chairman of the Plastics Advisory Committee of the National Security Industrial Association.

James W. Flynn of the Newark Section has been appointed market development manager of the Plastics Division, Celanese Corp. of America. He has been with Celanese since 1943, and for the past two years has served as assistant sales manager of the Plastics Division. Prior to joining Celanese, Mr. Flynn was associated with Allied Chemical Corp.

Francis V. Duffy has been named sales manager for nylon products for the Foster Grant Co., Inc., where he has been director of sales research in the Chemical Division for two years. A member of the Pioneer Valley Section of SPE, Mr. Duffy was formerly sales representative for the Dow Chemical Co.

Harry W. Cyphers, Jr., has been appointed product supervisor of alkyd molding compounds for the recently formed Plastics & Coal Chemicals Div., Allied Chemical Corp. Mr. Cyphers, a member of the Philadelphia Section, will coordinate all divisional activities pertaining to research, manufacturing, technical service and sales of Plaskon alkyd molding compounds.

H. W. Cyphers, Jr.

H. W. Lynch

H. Wilfred Lynch has been appointed vice president in charge of sales and new product development at Moxness Products, Inc., and was also elected to the board of directors. Mr. Lynch is a member of the Milwaukee Section of SPE.

Christian V. Holland has established consultation services specializing in plastics, pharmaceuticals and chemicals. Mr. Holland is a member of SPE's Chicago Section. His headquarters are located in Riverside, Ill.

Leslie J. Kovach, Pioneer Valley Section, has formed the Kovach Engineering and Consulting Co. in Boston. Mr. Kovach is president of the firm which offers a wide range of services to plastics manufacturers. He is a native of Hungary and was a pioneer in European plastics engineering. Since coming to the United States in 1949, Mr. Kovach has acted as consulting engineer to a number of plastics molding companies in the Boston area.

L. J. Kovach

W. J. Vogel

Woodrow J. Vogel has been appointed general manager of Reynolds Metals Company's new plastics sales division located in Richmond, Va. A member of the Baltimore-Washington Section, Mr. Vogel was formerly manager of the Reynolds plastics plant at Grottoes, Va., where he also directed sales operations. Before joining Reynolds in 1952, Mr. Vogel was with Goodyear Aircraft Corp. where he started one of the first aircraft metal fabricating departments using plastics for tooling.

Regional Technical Conference:

Plastics in Packaging

Sponsored by the Western New England Section
Grand Ballroom, Statler-Hilton Hotel, Hartford, Conn.
October 1, 1958

A one-day technical conference on "Plastics in Packaging" will feature nine papers. Subjects to be covered include a wide range of plastics materials and conversion techniques.

Advance registration fee is $9 for SPE members, $10 for non-members. Luncheon and preprint books are included in the price.

8:00 A.M.—Registration, Grand Ballroom Foyer.

Morning Session

9:00 A.M.—"Packaging with Rigid Urethane Foam"—A. J. Breslau, *Thiokol Chemical Corp.*

A new concept for package cushioning material is presented. Typical case histories will underscore design and performance characteristics of this versatile material.

9:30 A.M.—"High Density Polyethylene Film"—Robert Doyle, *Phillips Chemical Co.*

Slit, heavy-gage, blown tubing for thermoforming and thin-gage, quick-quenched film for overwrapping offer new packaging opportunities. Latest processing techniques will be discussed.

10:00 A.M.—"A Dynamic Index of Packaging Materials —A. J. Dragonette, *Bakelite Co.*

A comprehensive examination of the relative merits, economic and market positions of packaging materials, including metal, paper, glass and plastics, is projected through 1975.

10:30—10:45 A.M.—Break

10:45 A.M.—"Toxicity and Organoleptic Testing"—Dr. Louis C. Barail, *Consultant on Biochemistry and Toxicology.*

Tightening up of Federal regulations pertaining to toxicity and growing interest in the organoleptic characteristics of plastics packaging materials make such testing more important than ever.

11:15 A.M.—"Applied Engineering for Plastic Packaging"—R. Bruce Holmgren, *Package Engineering Magazine.*

Case histories will be used to illustrate how a packaging engineer selects and applies plastics materials.

12:00—1:45 P.M.—Luncheon

Principal Speaker: Frederick Leinback, *Executive Vice President, Riegel Paper Co.*

R. K. Gossett, *SPE National President*

Afternoon Session

2:00 P.M.—"New Polyolefins for Blown and Injection Molded Packaging" — William Bracken, *Hercules Powder Co.*

The technology, design and performance characteristics of the new polyolefins for rigid packaging applications are interpreted.

2:30 P.M.—"Vacuum Forming—The Industry Reporter's Viewpoint" — William Simms, *Modern Packaging Magazine.*

Trends, unique characteristics and current status are assessed.

3:00 P.M.—"Packaging Machinery Advances for Polyethylene"—R. Mattair, *E. I. du Pont de Nemours & Co., Inc.*

This paper is primarily concerned with film applications for automatic packaging.

3:30 P.M.—"Equipment for Packaging Based on the Extrusion Process"—A. Kaufman, *Prodex Corp.*

Reflections of American and European practices include new trends in extruders and auxiliary equipment.

RETEC Committee

Members of the RETEC Committee are: Chairman: Blakely R. McNeill, *Fuller Brush Co.;* Program: Robert R. Moyer and Eli A. Haddad, *both of Monsanto Chemical Co.;* Registration: Lawrence W. Freeman, *Plax Corp.;* House: Armand J. Vallieres, *American Cyanamid Co.;* Treasurer and Printing: Edward F. Duda, *Holyoke Plastics.*

Binghamton

Annual Dinner Dance

Leo J. Pranitis

A merry group of enthusiastic members and guests of the Binghamton Section gathered in their finery at the Carlton Hotel May 17th for the Second Annual SPE Dinner Dance.

The many dashing, debonaire plastics engineers escorted their becoming, bejeweled wives to the predinner cocktail party and get-together in the Starlight Room where the ladies were presented with long-stemmed roses (plastics, of course) as party favors.

Approximately 100 hungry patrons were served a bountiful smorgasbord. Then charming ladies assisted Joe Venne in the drawings for door prizes donated by the numerous industries represented.

Dancing to the varied tempo of Betty White and her Cosmopolitans gave the effervescent gathering a chance to demonstrate its terpsichorean prowess. There is no doubt that the ending of the affair at 1:00 A.M. came much too soon for many couples who were just getting the feel of the dance floor.

A sincere appreciation for an excellent job, well-planned and well-executed, is graciously conferred upon Emery Slaght, chairman of the affair, and his hard-working committee by the entire Binghamton Section.

Central Indiana

Annual Outing

Bill Neville

On June 21, the Central Indiana Section held its annual outing at the Indian Lake Country Club, Indianapolis. The outing committee did a swell job and should be given recognition. Gene O'Mahony was Chairman, assisted by Milt Brummer, John Anderson and Bill Miller. Also a vote of thanks goes to Walter Ellsworth and Harold Riley, Jr., for their fine assistance at this affair.

Good weather prevailed, although the fairways were a little damp in spots from prior rains. It was fortunate, however, that no members were lost from drowning.

A banker's handicap system was used to determine the golf prize winners. First prize of $16.00 went to L. Daffron. Second prize, an electric clock, went to Jack Connell, and B. Weisner won six golf balls for third prize.

The treasured SPE Golf Champion Cup for low gross went to Ed Rosenberg. L. Daffron won the cup for low net, while the SPE Golf "Chumpion" Cup went to M. Kerins for high gross. An impartial panel of guests voted Bill Hopkins winner of the "Best Dressed Member" Cup.

After the golf an excellent barbecued dinner was served, including such rare delights as fresh corn on the cob. Door prizes were given to members and guests; they were donated by companies associated either directly or indirectly with the Central Indiana Section.

Gene "Leaner" Quear won the horseshoe contest and was presented the Horseshoe Pitching Cup by Section Vice President Keith Weston.

A terrific volleyball contest was staged with the Western Electric "Short Circuits" coming out victorious. Captain Tony Mascari accepted the volleyball trophy for the winners.

Several complaints about the officiating were heard from the runner-up team, the Delco "Dead Ends." However, some of the regulars on the Delco squad had been observed breaking training regulations prior to the game and it was the opinion of many observers to have hurt their defensive plays. Credit should be given to co-managers Barney Hitchcock and Frank Adair of the "Short Circuits" for fielding such a well-trained, smooth-operating outfit. Co-captains Mike Kendricks and Ed Reynolds of the "Dead Ends" felt they weren't up to their usual top quality performance.

Spectator participation was the greatest ever at this event, and many appropriate comments were overheard during the play. Wayne Nicely made the game possible by very graciously lending the use of his door prize which just happened to be a volleyball set.

On June 19, an informal dinner was given at the Columbia Club, Indianapolis, in honor of the National Council members, meeting in Indianapolis the following day. Gene Quear, Councilman from the host Section, introduced S. D. Ransburg, Central Indiana Section President, who welcomed the Councilmen to Indianapolis.

The movie "The Sound and the Story" was shown. It told about phonograph record manufacture from recording to home production.

Central New York

Plastics in Tooling

Frederick E. Ruhe

The May meeting, held at Dellamorte's Restaurant, was called to order by Section President Jim Lampman. It was attended by 25 members and 5 guests. The President presented National Council news.

The speaker of the evening was Joseph Tierney of Houghton Laboratories in Olean. With the assistance of R. Park and D. Wolcott of the same company, Mr. Tierney presented an illustrated talk on "Plastics in Tooling."

He noted that the automotive and aircraft fields are the most active in the plastics tooling business. These industries have found that making models and Keller tools from plastics reduces the time and cost of operation. Although straight lines and angles can be made more readily of steel, compound curves and irregular shapes lend themselves to plastics.

The next regular meeting is scheduled for September.

Cleveland-Akron

Decorating and Coating of Plastics

Edward J. Haskins

The May meeting was called to order by Section President W. D. Martin. Membership Chairman H. E. Dutot reported on progress in new memberships: approximately half of the goal set for 1958 has been reached.

Thomas A. Bissell, National Executive Secretary, attended the meeting. He reviewed the hopes of the National Officers to attain more efficient communications and closer association between Sections and the National Administration.

W. A. Messina then introduced the speaker of the evening, John Scharnberg of the Bee Chemical Co., Chicago. Mr. Scharnberg spoke on decorating and coating of plastics, its range and limits, how it can be applied to create new markets in the increasing competition of the future.

Detroit

Sports Program

Russ Stanhope

The June meeting was held at Farmington Country Club. Ninety members and guests were in attendance for a fine afternoon of golf, followed by an excellent dinner and evening meeting. Low gross golf scores: John E. Donald—81, Bob Grant—82.

Section President John G. Slater presented the new Directors for the coming year: President, Malcolm A. Nichols, Manco Products; Vice President, Alexander A. Nick, Mercury Plastic; Vice President, Reinforced Group, George W. Wadtke, Fabricon Products; Treasurer, Arthur S. Linzell, Hydraulic Press Mfg.; Secretary, Gordon B. Thayer, Dow Chemical Co.; National Director, Iver J. Freeman, Reed Prentice Corp.

Lou Creekmur, Detroit Lions; Ted Lindsay, Chicago Black Hawks; and Marty Pavelich, former Detroit Red Wing, participated in a panel on sports.

Newark

Injection Molding

Fred W. Ducca

The May meeting was highlighted by a film and discussion of injection molding by automatic means. Lawrence A. Ulmschneider, a project engineer of Eastman Kodak Co., made the presentation which covered completely automatic injection molding from the hopper to the inspection station.

The film showed the injection machine, mold and accessory equipment with close-up and slow motion shots. Mr. Ulmschneider also showed slides of heating cylinders and pointed out what Kodak has done to use them most effectively.

New York

Mold Making

Charles C. Orr

The May meeting drew a record attendance of more than 250 members and guests. Three Professional Activities Groups were represented, including the newly-formed vinyl sub-group which by itself drew 150 members.

The reinforced plastics group witnessed a panel discussion on mold making. Moderator for the session was A. Harvey Johnson, Verly Plastics Co. Participants included S. Fialkoff, Camin Laboratories, Inc., Richard T. O'Connor, Devcon Corp., and John A. Kavanagh, Standard Tool Co.

Mr. Fialkoff discussed "Mold Making by Electroforming." With this process, precisely-dimensioned, highly-polished cavities can be made under conditions where other methods fail. One of the advantages of this method is that the surface finish of the mandrel is exactly reproduced in the cavity, thus eliminating expensive interior finishing operations.

"Devcon C—An Epoxy for Low-Cost Molds" was the subject of Mr. O'Connor's discussion. This material was shown to be satisfactory for short runs, since it can be made at low cost both for material and labor. Readily machinable with regular tools, the material exhibits good heat resistance permitting continuous operating temperatures up to 400° F, with intermittent operation as high as 500° F.

Mr. Kavanagh spoke on the "Shaw Process for Building Molds." This is the first major development permitting use of cheaper molds for applications calling for an intricate cavity and core with reasonable tolerances. At present, best results are obtained in casting beryllium-copper parts directly from models. Approximately 99% of the detail can be reproduced in the cavity. Steel hobs also can be cast at a substantial saving, and these hobs, in turn, can be used to cast beryllium-copper cavities and cores.

The first vinyl sub-group meeting was introduced by A. R. Miller, Ideal Toy Corp., who served as moderator. He discussed the necessity of adding heat and light degradation inhibitors to chlorinated polymers such as PVC.

Gerry P. Mack, M & T Laboratories, Inc., discussed "History and Development of Organo-Tin Stabilizers" and briefly reviewed their synthesis and chemical structure. He pointed out that this group of tetra valent stabilizers can be custom made to fit specific applications. Concluding his talk with an outline of new developments in this field, Mr. Mack announced a new group of vinyl tins that can be co-polymerized with vinyl monomers to give built-in stabilization.

"Barium-Cadmium Stabilizers" were explained by Charles F. Fuchsman, Ferro Chemical Corp., who emphasized the importance of synergism in their formulation. Important auxiliary stabilizers were shown to be chelators, zinc, and epoxy compounds. By careful control of heat and light stabilization, interesting photosensitive vinyl systems can be developed.

Abb L. Scarbrough, National Lead Co., spoke on "Lead Stabilization of Vinyl Resins." He traced the development which led to today's organic and inorganic lead salts which provide precise and powerful stabilization.

The thermo-forming sub-group was addressed by E. Bowman Stratton, Auto-Vac Co., whose topic was "A Survey of New Equipment, Materials and Techniques for the Forming Industry." Mr. Stratton discussed new materials for transparent packaging covering the oriented high-density polyethylenes, Mylar, Kralastic, Polyflex and butyrate. He outlined the production phases of pressure forming with special emphasis on product cost and speed of production.

(*Continued on next page*)

North Texas

Officers Presented at Second Meeting

Seated: Gen. Benjamin Kelsey, left; and Melvin Hare. Standing: William Smith, Branch Manager, Owens-Corning Fiberglas Corp., left; and James L. Neal, Regional Manager, also of Owens-Corning.

The second meeting of the North Texas Section was held June 23 at Western Hills Inn. Melvin Hare, president of Lone Star Plastics Co., Inc., presided at the meeting. Speaker of the evening was Gen. Benjamin Kelsey, consultant with Owens-Corning Fiberglas Corp.

Newly elected officers of the Section are: E. H. Swazey, President; Dave Daniels, Secretary; and Ernie Dourlet, Section Director. Others who will take office when elected to membership upon completion of application are: Tommy Tucker, Vice President; Hubert Poskey, Treasurer; Skip Cain, Jack Grimes, Dick Jenkins, Charlie Pritchard and Ray Uber, all Section Directors.

St. Louis

Picnic Boat Excursion

R. A. Karasek

The St. Louis Section held its summer social meeting on the "Thunderbird," Friday, June 13. This boat, chartered by the Section, goes up the Mississippi through the Alton Locks in the Chain of Rocks Canal.

Dinner was served on the boat, followed by dancing later in the evening.

The next meeting of the Section will be held in September.

New York Section Tours Laboratory

Members of the New York Section recently toured the laboratories of W. R. Grace & Co., Polymer Chemicals Div., Clifton, N.J. One of the highlights of the tour was a demonstration of an improved technique in the injection molding of high-density polyethylene. About 100 members were present.

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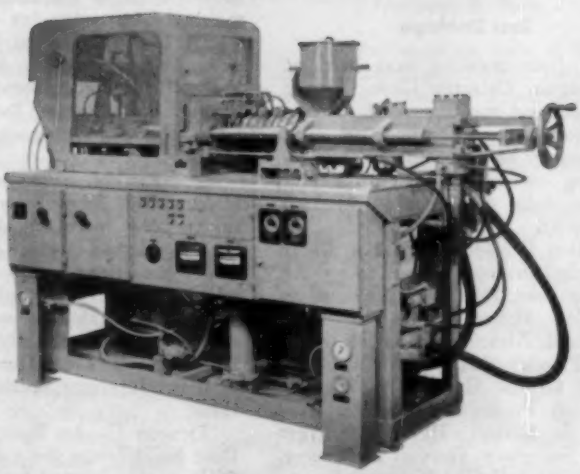

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PLASTICS AROUND THE WORLD

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UNITED STATES

MATERIALS IN DESIGN ENGINEERING

March, 1958

Abstracter: L. S. Buchoff

Thermal Insulation Materials— R. J. Fabian

Plastics foams and cellular rubber are among the thermal insulation materials described in this excellent comprehensive article. Prefoamed and foamed-in-place polystyrene, have low thermal conductivity, low water vapor transmission, and they are not affected by sub-zero temperatures.

The principle advantage of silicone foams, is their ability to withstand high temperature; urethanes have excellent mechanical strength. Phenolic, urea formaldehyde, and polyvinyl chloride foams are also discussed.

Cellular rubbers are noted for their light weight, availability in soft or hard forms in a variety of shapes, high resistance to moisture and vermin, and they provide easily cleaned, sanitary surfaces.

Two Acrylic Resins for Reinforced Plastics—M. S. Ziegler, W. H. Calkins and W. M. Edwards

The first all-acrylic laminating resins are described, one for high- and one for low-pressure fabrications.

Laminates of these resins are superior to those of epoxy and polyesters in their retention of gloss, light transmission, color, and surface smoothness after weathering.

The acrylic laminates have exceptional impact resistance, and maintain their physical properties well above 212°F. The resins have a long shelf life and are used with the same molding cycles, pressures and temperatures as general purpose laminating resins.

How Polyether Foams Compare— M. J. Sanger, G. T. Gmitter and E. M. Maxey

The polyether approach to providing acceptable urethane cushioning materials consists of creating a new backbone polymer based on polyether glycols.

In such foams, the ether linkage replaces the ester linkage. Major benefits offered by polyether foams in comparison with the adipic polyester types are:

1. A relatively smooth loading curve, greatly reducing the plateau effect.
2. High resiliency or rebound.
3. A relatively high degree of resistance to humidity aging and to chemicals.

Adipate foams have a higher energy loss than polyether types, and thus are more suitable for shock absorption applications.

★

ELECTRICAL MANUFACTURING

April, 1958

Abstracter: W. A. Kelley

Synthetic-Fiber and Wool Felts-Their Design Characteristics and Uses—T. J. Gillick, Jr.

A comprehensive review of a new class of engineering materials including wood, synthetic fiber and composite felt materials used in design of electrically energized equipment. Classifications covered are different types of felts and their uses, mechanics of natural and artificial felting procedures, metallic and nonmetallic combinations, physical and chemical data charts and curves, and some experimental materials for future use.

Vacuum-Molded Epoxy Cast-Resin Applications—H. R. Lucas

Changing from an asphalt-impregnated insulation structure to an integrally molded and impregnated epoxy resin insulation structure in an instrument transformer application gave a better physical appearance, improved mechanical strength with protection of delicate parts and coils, improved resistance to thermal cycles and vibration, and improved heat transfer in electrical coils through filling of voids and better heat flow. The entire transformer is impregnated and cast in one molding operation using a low pressure vacuum molding technique which is adaptable to mass production.

★

MECHANICAL ENGINEERING

April, 1958

Abstracter: Philip G. Fleming

Plastics Engineering 1956-1957—A Review of Developments—E. E. McSweeney and R. G. Heiligmann

The past year has witnessed a strong growth pattern in plastics engineering. Notable improvements were made in proprietary materials and several newcomers are now on the scene.

Limited commercial application of radiation techniques as applied to plastics are of note.

Of major importance has been the accelerated development of excellent and highly useful engineering data. Plastics are finding more applications as materials of construction and materials in their own right.

The authors present a short, news-release type survey of foreign developments, materials, new products, processing, equipment and standards and education.

The listing of references appended, in itself, is ample recompense for perusal of the article.

★

FRANCE

INDUSTRIE DES PLASTIQUES MODERNES
April, 1958

Abstracter: Hans Mayer

The Development of a Plastics Compound for the Shoe Industry—A. Mathé

By the nature of the end product, a plastics material used in the shoe industry must be thermoplastic. Specifically, a polyvinyl chloride-type material seems to meet all needs better than any of the other materials available. The development of the proper compound for the purpose is described through all its phases. Specifications on plasticizers, stabilizers, flow characteristics, heat resistance, lubricants and colorants are given.

★

GREAT BRITAIN

BRITISH PLASTICS
March, 1958

Abstracter: Evert A. Mol

Polycarbonates—

The article mentions four main routes for the preparation of polycarbonates. The most likely route appears to be the reaction of 4.4′ dihydroxy diphenyl alkanes with phosgene in alkaline conditions. The polycarbonates thus prepared have molecular weights up to 150 000. The polycarbonates have been announced almost simultaneously by Bayer Company in Germany and General Electric Company in the United States.

The information presented in the article appears to have been taken principally from publications of General Electric. Interesting is a tabulation of the electrical and physical properties of polycarbonate (G. E.'s Lexan) compared with polyamide, polyacetal, cellulose acetate, cellulose acetate butyrate, polystyrene, polyethylene (low density) polyethylene (high density) and polyvinyl chloride.

Lexan can be molded if dried in conventional ways; heated molds usually give the best results. Mold shrinkage is in the order of 0.005-0.007 in./in. The molding temperatures can be varied over a relatively wide range; the temperatures normally used are 525° - 575°F. Overheating does not seem to harm the polycarbonate resins, but darkening in color and a reduction in toughness can be caused by too much overheating. The polycarbonates can be dissolved in chlorinated hydrocarbons, dioxane, and creosols, and thus can be used for solution coatings.

The Determination of Moisture Permeation Rate Through Polythene Cable Glands—D. W. Glover and A. J. Cleaver

The point of entry of polyethylene sheet cable in the repeaters used in long distance submarine telephone cables must be so water-tight that they allow less than 2.5 mg of water per year to enter the inside of the repeater. A method to measure the water vapor leakage must be very accurate to be conclusive in a relatively short time.

Two methods are discussed: one using a dew point or frost point thimble to determine the water vapor pressure inside, and the other using tritium oxide as a radioactive tracer.

Apparatus and results of these tests are briefly discussed. They indicate that further work is necessary.

Measurement of PVC Brittle Point—H. O. Williams

The brittle point of PVC sheet and PVC covered fabric is determined by letting a spring-loaded plunger hit a bent test piece in an alcohol bath cooled with solid carbon dioxide. The cold crack temperature or the brittle point is the temperature at which there is a 50 per cent chance of the piece breaking under the impact of the plunger.

The effect of the sample thickness and plunger speed have been checked, together with the influence of plasticizer content and filler percentage. A comparison is also made with the method of Clash and Berg, which is better known to most American readers.

★

CANADA

CANADIAN PLASTICS
March, 1958

Abstracter: Samuel S. Oleesky

The March issue is devoted to descriptions of properties, uses and molding techniques for linear polyethylene. The forum in print includes:

D. M. Taylor, "A Practical Look at Linear Polyethylene"
Hugh Cairns, "Applications-Potentials of Linear Polyethylene"
Charles Atherton, "Sheet Applications in Linear Polyethylene"
J. E. Simpson, "Better Color Dispersion for Linear Polyethylene"
Anonymous, "New Additive Combinations Will Inhibit Oxidation of Polyethylene"

The magazine editor has done a good job in assembling these papers into what amounts to a short handbook on this polymer. The titles of the articles are self-explanatory, and the plastics engineer interested in linear polyethylene will do well to preserve this issue of the magazine as a source of future reference.

★

GERMANY

KUNSTSTOFFE
February, 1958

Abstracter: Charles S. Imig

Combination of Different Packaging Materials—Prof. Dr. H. Berger

The ability to enhance the properties of a packaging material through combination with another material is discussed. Among the plastics films discussed are polyethylene, cellophane, nylon and Pliofilm. A table of physical characteristics is given.

Packaging Uses of Plastics in the Chemical Industry—Ernst Ramspeck

The use of plastics such as nylon, cellulose acetate, cellulose acetate butyrate, styrene - butadiene - acrylonitrile polymers and polycarbonates for the chemical industry is discussed. Particular characteristics of each material which may be utilized to advantage are emphasized.

Developments and Standardization of Plastics Packaging Films—Dr. Ing Otto Herrmann

A number of more important plastics films are discussed including cellophane, vinyl, polyethylene, acetate, saran, Mylar, Pliofilm and nylon. It is emphasized that basic

physical properties of the resins, or for that matter, of selected film sample are of little value to the end user. An example of this would be the variability of tear strength with the degree of biaxial orientation. As a result, meaningful tests must be performed on the end product. This is hampered by the lack of standard test methods. A summary of important properties of the above films is given.

Offset Printing of Plastics Products—Hansjorg Grauel

Plastics packaging materials are easily printed in either single or multicolor presses by the offset process. The proper ink selection is very important to the process. In addition to inks being discussed, adhesion, drying and protective lacquers are also covered.

Closures for Thin Wall Plastics Containers—Dr. Ing. H. Behringer

The relationship of thin wall plastics containers to other packaging media is discussed. A welded closure is as economical a type of closure from a production standpoint but it is not generally acceptable to the consumer. Closures are shown which are easily removable and thus more readily acceptable.

The Label—Part of the Package—Friedrich Beck

The importance of the label with its trade name, directions and similar data is increasing with the increasing use of transparent packaging. The gummed label is losing out to the self adhesive label which is applied with a synthetic resin adhesive or heat sealing.

Plastics Bottles and Their Significance—Kurt Andree

The use of plastics bottles, and more especially, blow molded polyethylene bottles have grown themselves over the years. The use of polyethylene bottles is spreading to large containers, up to 13 gallons, for agricultural, automotive and chemical use.

Screen Printing Onto Plastics—Erich Mertes

This process is especially adaptable to the printing of plastics and in fact some plastics may only be printed this way. Cellular and deep-drawn parts can be printed. The prime factor is the proper choice of ink. Polyethylene must be heat treated prior to printing.

★

DER PLASTVERARBEITER

January, 1958

Abstracter: Leo Fischer

Superstyrol, A New Thermoplastic Sheet Material With High Strength—Heintz Jungnickel

Superstyrol is a styrene-butadiene-acrylonitrile copolymer. Generally, it is sold in 5- to 6-mm thickness. It is especially good at low temperatures down to −10°C. It is easily formable and is recommended for use in photographic and chemical trays, type case trays and helmets.

Accident Prevention with Injection Molding Machines—K. Treydte and D. Liebhardt

This article gives a series of safety devices which should be installed in all injection molding machines which are of an older vintage and do not have them. Methods of building and installing these devices are given.

Extrusion Technique—Jean Peynichon

This is the eighth installment of a very thorough study of extrusion techniques. The subject is heat and temperature regulation.

★

AUSTRALIA

AUSTRALIAN PLASTICS AND RUBBER JOURNAL
February, 1958

Abstracter: Albert Lightbody

New Markets in Refrigeration—

The use of plastics in refrigeration units and air conditioners covers most of the parts at the present time with the exception of the principal structural members. This includes the food liners, food trays, drawers, insulation and electrical housing. The possibilities of further development using glass-reinforced plastics are discussed. One refrigerator actually uses 24 pounds of plastics in its construction.

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Effect of Plastics . . .

(*continued from page 37*)

A test was made to determine whether any of the 23 plastics being investigated were toxic to the organisms used in the previous experiment. Since no deleterious effect on the test bacteria had been noted when 20% of Super Dylan or Teflon was used, 10% concentrations were employed in this experiment. The addition of this amount of each plastics to 50 ml. of raw whole milk was calculated to be approximately equivalent to the quantity which would be in contact with the milk in a plastics collecting and shipping bag. All samples were held at 9°C and plate counts were made after 0, 24, and 48 hours.

The findings are given in Table 3. On the whole, there is no great variation in the numbers of micrococci developing in the presence of the different plastics. In most cases the numbers of streptococci increased when held for 48 hours at 9°C. This experiment indicated that none of the plastics exhibited any pronounced inhibitory effect on the test organisms.

To determine the effect of nine representative plastics on the microflora of abnormal milk such as might be submitted to a laboratory for bacteriological examination, a sample was obtained from a cow whose teats had been frozen. The milk contained small flakes or pieces of curd and showed some tendency to separate on standing. Thirty ml. portions of milk were added to milk dilution bottles along with 6 g of plastics. Plate counts were made on M-P H agar and on bovine blood agar. On the latter medium, total counts as well as a count of any colonies showing hemolysis were made. The findings are given in Table 4. The control counts are for the milk without added plastics.

In most instances, little variation was found between the standard plate counts on M-P H agar and the standard plate counts on blood agar of the abnormal milk with or without added plastics. Hemolytic streptococci and micrococci accounted for more than half of the microbial population, and there was no indication that the plastics tested exhibited any toxicity towards these organisms.

Summary

The effects of 23 plastics in pellet and powder form on stock cultures of *Micrococcus pyogenes* var. *aureus* and *Escherichia coli*, on freshly isolated strains of a micrococcus and a streptococcus from abnormal milk, and on the microflora of raw milk from an injured udder were studied. On the basis of quantitative bacteriological tests, there was no evidence that the plastics of types including polyethylene, polyvinyl chloride, acrylic, nylon, trifluorochloroethylene and polytetrafluoroethylene, polystyrene, ethyl cellulose and cellulose acetate butyrate were toxic to the microorganisms investigated. Results indicate that it should be feasible to fabricate a single service plastics bag for transporting aseptically collected milk samples to the laboratory without the plastics studied being detrimental to the organisms present.

Acknowledgements

The authors are indebted to the following: Mr. E. L. Cole, P. E., Biological Engineer, for suggesting and helping to finance this study; Drs. Hadleigh Marsh and J. E. Catlin of the Veterinary Research Laboratory at Montana State College for providing milk samples; Dr. A. Jasmin of the Montana Livestock Sanitary Board for providing cultures; and Mr. R. T. Henson of Flexible Products Company for arranging with different manufacturers to submit plastics for testing.

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(3) Tiedeman, W. D. and Milone, N.A. 1955. A study of plastic pipe for potable water supplies. Bulletin published by National Sanitation Foundation, School of Public Health, University of Michigan, Ann Arbor, Michigan, 1-90.

(4) United States Testing Company, Inc., Hoboken, New Jersey. Report No. 12286, March 5, 1956.

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PLASTICS RESEARCH REPORTS

Synthesis and Characterization of New Vinyl Polymers

L. E. Coleman, Jr., and W. S. Durrell, Wright Air Development Center, U. S. Air Force. Jan. 1958. 24 pp.
(Order PB 131669 from OTS, U. S. Department of Commerce, Washington 25, D. C. 75¢.)

Polymerization characteristics of four classes of new experimental monomers were determined, and a preliminary evaluation was made of the potential of the resulting polymeric products as thermally-stable, solvent-resistant plastics and elastomers. These main classes of monomers were studied: fluorine-containing acrylates, styrenes, and unsaturated ketones; and ferrocene-containing unsaturated ketones. Among the results, it was found that the perfluoroalkyl propenyl ketones copolymerize with a variety of comonomers such as vinyl acetate, styrene, and butadiene to give products ranging from powders to elastomers. 1-alkyl-1-hydroperfluoroalkyl acrylates copolymerized readily and formed tough, rubbery homopolymers with good thermal stability and low swell in diester-type lubricants. *trans*-Cinnamoyl ferrocene formed copolymers with a variety of comonomers, but low conversions, copolymers, or copolymers containing small amounts of cinnamoyl ferrocenes were obtained.

Measurement of the Thermal Properties of Various Aircraft Structural Materials

P. C. Covington and S. Oglesby, Jr., Southern Research Institute for Wright Air Development Center, U. S. Air Force. Aug. 1957. 71 pp.
(Order PB 131432 from OTS, U. S. Department of Commerce, Washington 25, D. C. $2.00.)

Thermal properties were measured of a group of metal and plastics structural materials which included honeycomb cores, a foamed-core sandwich panel, a laminated panel, and sandwich panels with various honeycomb cores and facing materials. Measurements were taken of specific heat and thermal conductivity from —50 to 600° F, and thermal expansion from —100 to 600° F. Physical properties determined for the materials included Barcol hardness, resin content, and flexural strength.

Industrial Literature

Adipic Acid

A technical encyclopedia on adipic acid, covering properties, reactions, current uses and potential applications, has been published by E. I. du Pont de Nemours & Co., Inc., Polychemicals Dept., Fairfax, Wilmington 3, Del. Tables and charts explain the use of this material in the production of synthetic fibers, urethane foams and other plastics. Information is arranged for easy reference. Price: $1.00.

Vinylpyrrolidone

The applications of vinylpyrrolidone are profusely illustrated with technical tables and charts in a brochure offered by Antara Chemicals, 435 Hudson St., New York 14, N.Y. The brochure details copolymerization of vinylpyrrolidone with other monomers for a wide range of products such as adhesives, coatings and finishes, cosmetics, glass-laminating resins, lube-oil additives, protective colloids, synthetic fibers and textile sizes.

Adhesives, Coatings, Sealers

Government specifications for a wide variety of adhesives, coatings and sealers are listed in a catalog published by Minnesota Mining & Mfg. Co., Adhesives, Coatings and Sealers Div., 423 Piquette Ave., Detroit 2, Mich. The catalog lists, in numerical form, Military, Army and Federal specifications, their definitions, and the corresponding 3M adhesive, coating or sealer that meets these specifications.

Crotonic Acid

Properties, reactions and applications of crotonic acid are described in Brochure TDR #A-101, issued by Eastman Chemical Products, Inc., Kingsport, Tenn. The brochure outlines numerous reactions of crotonic acid involving its double bond and its carboxyl group. Among the various applications suggested is its use as an intermediate in forming molding polymers and copolymers, protective coating resins and plasticizers.

High Vacuum Vapor Pumps

Technical information on a wide range of high vacuum vapor pumps is presented in a well-illustrated booklet offered by Consolidated Electrodynamics Corp., Rochester Div., Rochester 3, N.Y. Included in Bulletin 6-1 are: non-fractionating diffusion, fractionating diffusion, ejector and diffusion-ejector type pumps as well as many accessories and supplies.

Organic Chlorine Compounds

Eleven organic chlorine compounds available in commercial quantities are described in a 45-page booklet published by Union Carbide Chemical Co., 30 E. 42nd St., New York 17, N.Y. Physical and physiological properties, handling and storage data, specifications and test methods are covered. The materials discussed are ethylene dichloride, Chlorasol fumigant and solvent, propylene dichloride, trichlorethane, butyl chloride, 2-ethyhexyl chloride, dichlorethyl ether, dichlorisopropyl ether, triglycol dichloride, ethylene chlorhydrin and epichlorhydrin.

Sodium and Potassium Borohydrides

Properties, reactions and handling requirements of sodium and potassium borohydrides are discussed in a 34-page technical manual available from Metal Hydrides, Inc., Congress St., Beverly, Mass. Included in the manual are detailed explanations of reactions in aqueous and non-aqueous solvents. Among the more important commercial uses of the borohydrides explained are: reduction of aldehydes and ketones in water, alcohols or amine solvents; cellulose reductive bleaching and stabilization; carbonyl clean-up; and hydroboration of olefins. The compounds are used in the pulp and paper, pharmaceutical, chemical and allied industries.

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Book Reviews

THE PENTAERYTHRITOLS

Evelyn Berlow, R. H. Barth, J. E. Snow, A.C.S. Monograph #136, Reinhold Publishing Corp., New York, 1958, 317 pages, $10.00.

Although the reviewer started to skim through this book in order to obtain a fair picture of its usefulness, he found himself reading it in detail for two reasons: First, it is packed with research ideas which can be applied by analogy to many fields. Second, it is practically impossible to skim through an encyclopedia or a dictionary. The 300 pages, although very well ordered in several ways, are packed full of short facts, which in many cases are unrelated except to the general title of the section. One feels confident that a thorough search of the literature has been made up to 1957, not only on the pentaerythritols, but all their products and their applications, as well as those of the pentaerythritols. Every statement is well referenced to a list at the end of each chapter. These references are used again in the separate author index. It is obvious that a reasonable compromise has been reached between a need for more detailed information on each statement and a book which would not be too long. The result resembles a card catalogue from which one must usually turn to the original literature in order to obtain enough information to serve a practical purpose.

It appears that the literature on pentaerythritol is so extensive that this book will fill a definite need for many people. This type of condensed information, however, should necessitate an index almost as long as the text if it is to be of the greatest usefulness. The use of the index is best supplemented by a search through paragraph headings, not only in the chapter headed by the title most pertinent, but in the rest of the chapters as well. For instance resins made from various pentaerythritol derivatives may be found in many paragraphs in addition to those in the chapter with "resins" in its title, but not in the index under "resins". As another example, the effect of compounds on living organisms is treated in an analogous manner. The difficulty in arranging a satisfactory index to such an array of complex compounds is realized but the reviewer questions the choice of the first part of the name as the choice for indexing and for the compounds in the many long but thorough tables of compounds—especially when the first word happens to be such a word as "tetrakis". At least two word usages, which may be acceptable in the trade, aroused some question in the reviewer's mind. These were in "tetrakis" the use of the "kis" which is not needed to identify the compound structure, and the use of pentaerythritol instead of pentaerythrityl, by analogy with ethyl acetate, when naming such compounds as "pentaerythritol distearate". Furthermore, the latter is indexed as distearate among the 10 columns in the index under "pentaerythritol", but not as a stearic acid derivative under the "S". This practice of indexing a compound under the broadest classification and not necessarily under a more distinctive key word, makes it difficult to find. The index is (probably necessarily) so brief that chromatographic analysis, for instance, is not listed although the text infers that it is important.

The frequent structural formulae and tables are very helpful but the order of arrangement in even the long tables is not obvious. One pet peeve of the reviewer is illustrated in this book also. One has to search the table of contents as well as the index since the chapter subjects do not appear in the index. This is not difficult to do, however, in a short book. The index problem has been helped in some other texts by a separate or included listing of compounds arranged by element composition such as C_6H_5Cl.

None of the above criticisms can be construed as decreasing the value of this book as the only compact key to the literature of pentaerythritol and its compounds and uses. Incidentally, not one typographical error was encountered.

Robert B. Bennett
University of Florida

INDUSTRIAL RESEARCH LABORATORIES OF THE UNITED STATES, Tenth Edition

Compiled by James F. Mauk. Publication 379, National Research Council, Washington D.C., 1956. 560 pp., $10.00.

DIRECTORY OF INDEPENDENT COMMERCIAL LABORATORIES PERFORMING RESEARCH AND DEVELOPMENT

National Science Foundation, NSF-40, U.S. Government Printing Office, Washington, D.C., 1958. 59 pp., $0.40.

The first of these two books contains an impressive list of 4,834 industrial or commercial laboratories located in the United States. Listings give the names and addresses of the laboratory; name of the president, officers and heads of departments; size of the staff; and principal activities. There are 33 per cent more listings than on the ninth edition published in 1950.

This book serves two purposes. It acquaints the reader with the staff and activities of research laboratories managed by American industry and specialized in many fields. It also lists the laboratories which do research and testing on a commercial basis for the industry and the public at large.

The second book gives in its concise form a compilation of the commercial laboratories. It enables the reader to discriminate between these commercial laboratories, as therein described by their owners, and these laboratories managed by professional consultants. Its listings are very similar to those in the first book, but there are a few discrepancies. However, as it is, and at its low cost, this booklet is worth buying.

Louis C. Barail

QUALITATIVE ANALYSIS

Therald Moeller. 1st Edition, McGraw-Hill Book Co., Inc., New York, 1958. 550 pp., 6.50.

This is an excellent text book on the subject of Qualitative Analysis. Although the book is written for college students of this subject, more advanced readers may find it a suitable refresher course.

The book is divided into three parts covering first, principles of solution chemistry; second, chemical characteristics of the more common ions; and third, the laboratory investigation and analysis for the ions studied. There is also a fine appendix supplying many of

the necessary tables and charts for adequate and proper use of the text book.

The author has taken a novel approach in that the theoretical discussion and the laboratory work on the anions precedes that of the cations. This is quite a departure from the general scheme of study on this subject. Further, the material on the anion is much more extensive than that usually found in a book of this type. As a result, a student becomes more fully acquainted with the chemistry of the non-metallic elements contained in the anions studied in this text and gives the student a much better background for the study of the cations that follows.

Further, the division of the book into three sections covering the fundamentals of solution theory and equilibrium, the chemical characteristics of the common ions studied, and the laboratory investigation of these ionic species makes the book easily adapted to student work. Assignments can be made simultaneously from all three sections in order to bring about an overlap of theory and practice.

The book is well written, and all of the chapters end with problems the solving of which helps in the understanding of the text. The book will have very limited use for the plastics engineer, but would be an excellent text book for those studying Qualitative Analysis.

Separate schemes are presented for semi-micro analysis of the cations and anions. This includes both the use of hydrogen sulfide and phioactamide. In my opinion, the book presents an excellent foundation of fact and theory for subsequent course work in chemistry.

Robert Steinman
Garan Chemical Corp.

MATERIALS HANDLING APPLICATIONS

D. Oliphant Haynes. Chilton Co., Philadelphia, 1958. 381 pp., $12.50.

The title of this interesting book is somewhat modest. It gives no clue to the fact that the book is actually an Encyclopedia on handling of materials. Be it ball bearings, fish or rolls of newsprint, the reader can learn how to pack it and how to handle the article from the time that it is made to delivery at its final destination.

The book is a handy reference for occasional applications and as a full time reference for the seasoned engineer. It is also a source of information for those who wish to round out their overall knowledge about such things as barrels, kegs, crates, bales, cans, and many other containers. The reader can learn the differences between a pry and a hand truck; between a pillar crane and a gooseneck crane; between end and side loaders, and between the many different kinds of yard cranes.

A book such as this has been written by an industrial engineer to fill a much needed place in reference literature. It teaches how to conduct studies of material handling problems in their entirety and how to find the best solutions to these problems. Chapter by chapter, the book shows how to analyze motions, equipment functions, methods of packing, handling, work areas, transportation and many other fine details. The last chapters explain how to make and evaluate material handling surveys.

It is predicted that Mr. Haynes' book will be accepted enthusiastically by industrial engineers and that it will become an important reference.

John D. Czarnecki
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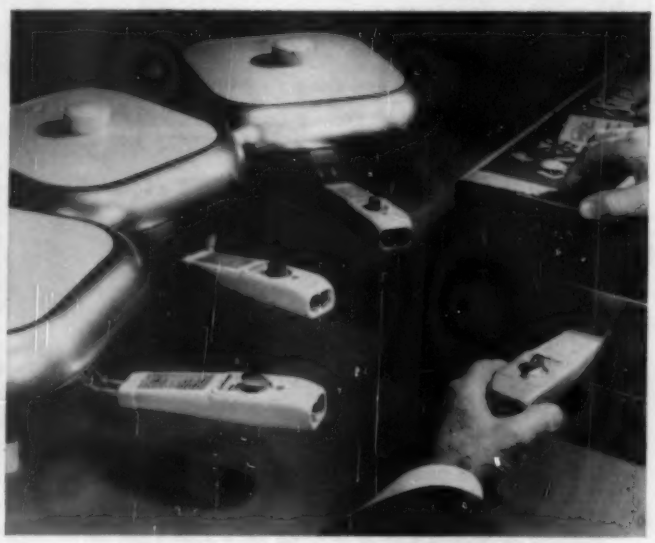

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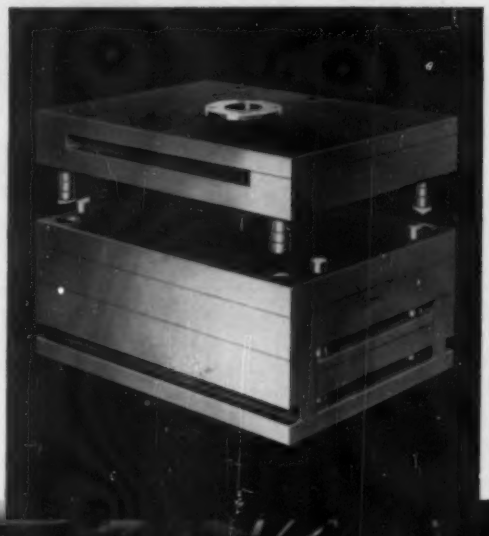

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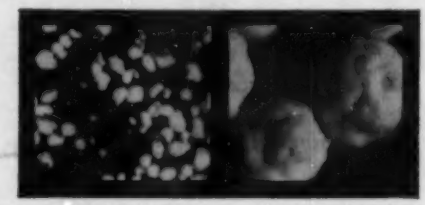

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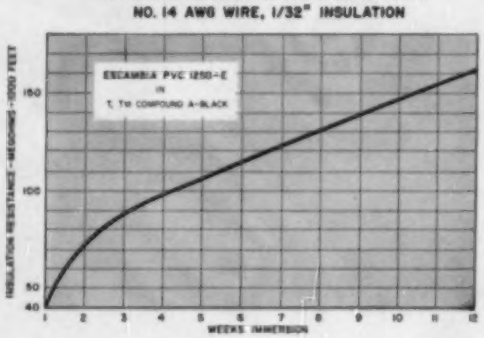

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